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ELEMENTARY
CHEMICAL ARITHMETIC.

ELEMENTARY
CHEMICAL ARITHMETIC

WITH 1100 PROBLEMS.

BY

SYDNEY LUPTON, M.A.

ASSISTANT MASTER IN HARROW SCHOOL.

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PREFACE.

THE use of numerical problems on the properties and reactions of substances, as a means of emphasizing statements made in lectures, was suggested many years ago by Mr Galloway, and has become to some extent common among teachers of chemistry in this country, but has been far more systematically and thoroughly adopted by Professor Cooke and other chemists in America.

The present book is an endeavour to put into a concise and simple form suitable for beginners in chemistry and for tyros in mathematics a considerable quantity of matter which is usually given by teachers in the form of manuscript notes, and to furnish a collection of easy numerical examples, a few of which may be set at the conclusion of each lecture.

The problems are arranged in the order of the chemical reactions on which they depend, and not according to the mathematical methods used in their solution, in the hope that they may tend to fix in the mind of the learner the chief points which he has just heard dwelt upon. They are not arranged according to their difficulty, since this depends to a considerable extent on the mind of the individual pupil and on the bent and scope of the master's teaching, but each chapter is divided into an elementary and an advanced portion. For the sake of simplicity atomic instead of molecular equations and approximate instead of exact values have been very frequently given.

After some doubt and deliberation the answers are placed at the end of the book. In the elementary portion of each chapter they have been obtained by the use of 22·4 litres as "two-volumes" according to the proposal of Professor Williamson and of $\frac{1}{273}$ as the coefficient of expansion of a gas, in the advanced portion the more exact values 22·32 litres and ·00367 have been used and the calculations have been usually made by four-figure logarithms.

A considerable number of the usual tables will also be found, some of which have been recalculated from recent results. The approximate atomic weights used throughout have in some cases of conflicting evidence been chosen to preserve well-known numbers or to avoid labour in calculation, and not from the assurance of their accuracy. The values calculated by Professor Clarke as the most probable results of all the best experiments are also given for the use of those who may wish to work with the greatest attainable precision.

With some diffidence an introduction has been prefixed to the examples, which is not intended in any way to supersede oral instruction, but if possible to supply two different wants.

Boys and masters too often find when separated that something, which a few hours before seemed to be clearly and securely grasped, has disappeared in a most bewildering fog. The only resource of the boy is then something written down or in print, and it is hoped that the necessarily short explanations given may suffice to recall the missing ideas, though want of space has precluded that fulness of illustration which is required to bring an entirely new subject home to the mind. Again, the authors of original memoirs and the larger text-books frequently give only in outline calculations which belong more properly to arithmetic than to chemistry, and boys weak in arithmetic are often puzzled to supply the intermediate steps.

The first eight sections of the introduction deal with portions of arithmetic which are subsequently required, and which experience has shewn are often omitted or not sufficiently grasped in the ordinary course of arithmetic, these may be easily read by anyone who has mastered the "first four rules," vulgar and decimal fractions, any method of working "Rule of Three" sums, and the definitions of the first book of Euclid. The following sections are devoted to the different cases in which Chemistry calls in the aid of Arithmetic without demanding a knowledge of the higher Mathematics. Common mathematical formulæ are simply given as facts to be remembered, since the proof in many cases demands greater knowledge than my readers are assumed to possess. The harder sections, which may be omitted by beginners, are marked by an asterisk as a guide to anyone who may be working without the assistance of a master.

The introduction is of necessity a compilation from all the ordinary sources, and the problems are the results of collecting for several years, at first solely with a view to private use; hence an apology may in a few cases be due to authors in whose footsteps I have too closely trodden, and without whose labours this book would never have been undertaken.

My grateful thanks are due for some problems and for much valuable advice to numerous friends, amongst whom I have special reason to mention Professor Tilden, Rev. T. N. Hutchinson, A. G. Vernon Harcourt, H. G. Madan, and W. A. Shenstone, Esqrs. I shall also be much obliged to anyone who may send corrections and suggestions to myself directly or through my publishers.

S. L.

HARROW,
June 19, 1882.

INTRODUCTION.

Sections and paragraphs marked by an asterisk may be omitted on the first reading.

ARITHMETIC.

(1) APPROXIMATION.

When arithmetical processes are applied to working out the results of experiments, there are many cases in which the ordinary methods may be shortened without any loss of accuracy and with a considerable saving of labour.

All numerical results obtained by experiment are liable to more or less experimental error, so that the correct number is never obtained, but only one more or less closely approximating to it. Thus, if the diameter of a six-penny piece be measured with an ordinary foot-rule, it is found to be ·75 of an inch; but owing to imperfections in the rule and in the observer the true value may be either ·751 or ·749 of an inch.

Experiments then being imperfect it is a misleading and useless labour to obtain results carried to a large number of decimal places by arithmetic, when the second or third figure may be incorrect owing to experimental error. Thus if it be required to calculate the length of the circumference of the six-penny piece from the measure of the diameter just given, it is known that the circumference of a circle is ($\pi =$) 3·14159265 &c. times the length of the diameter, and hence in the given case the circumference is

$$\cdot 750 \times 3{\cdot}14159265 = 2{\cdot}3561944875 \text{ inches.}$$

But the diameter may in reality be either ·749 or ·751 of an inch, and hence the circumference may be either

$$\cdot 749 \times 3{\cdot}14159265 = 2{\cdot}3530528948 \text{ inches,}$$

or

$$\cdot 751 \times 3{\cdot}14159265 = 2{\cdot}3593360801 \text{ inches.}$$

Since then the experiment is not sufficiently accurate to decide whether the fourth figure ought to be 3, 6, or 9, all the figures to the right of it are of no value, and in fact misleading, since they claim for the experiment an undue amount of accuracy.

A chemical experiment is a good one if the numerical results are true to $\frac{1}{1000}$; in certain cases, if special precautions are taken, the results may be correct to $\frac{1}{10000}$. In general then arithmetical methods may be modified in any manner to save labour so long as the working is correct to the fourth significant figure.

In approximate working it is more convenient to use decimal than vulgar fractions, because there is no trouble in reducing the former to common denominators and it is easy to estimate the error introduced by omitting any portion of the decimal. Thus if the value of π be taken as 3·14 instead of as 3·14159265, the error introduced is rather over ·001 and the result will be incorrect by about $\frac{1}{3000}$ of the whole.

If the portion of a decimal omitted commences with 5 or a higher figure, the last figure retained must be strengthened by the addition of 1. Thus in the case of 3·14159265, if all beyond the fifth figure is to be neglected, 3·1415 is too small by ·00009, but 3·14156 is too large by only ·000008, hence the error in the second case is only about $\frac{1}{11}$ of what it would have been had the last figure retained not been strengthened.

In dealing with large numbers it is frequently convenient to write them as a single figure in the unit place followed by decimals and multiplied by 10 raised to the required power. Thus a ton contains 15680000 grains, which may be written $1{\cdot}568 \times 10^7$.

(2) MULTIPLICATION.

When two decimals are multiplied by the common method, a number of the decimal figures, which are so obtained, are useless owing to experimental error. The following method only makes use of sufficient figures to obtain the required degree of accuracy.

(i) Count off after the decimal point in the multiplicand (annexing ciphers if necessary) as many figures of decimals as are required in the product.

(ii) Below the last of these write the unit figure of the multiplier, and write its other figures in reversed order.

(iii) Multiply by each figure of the inverted multiplier, neglecting all figures of the multiplicand to the right of that figure, except to find what is to be carried; and let all the partial products be so arranged, that their right-hand figures stand in the column of the unit figure of the multiplier.

(iv) Cut off from the sum of these partial products the required number of decimal places.

For greater accuracy it is preferable to calculate one figure more than necessary, and to cut it off from the answer.

Thus, to multiply 3·14159 by 19·14383 correctly to three places of decimals,

$$\begin{array}{r} 3{\cdot}141{,}59 \\ 383\,419\,1 \\ \hline 31\,416 \\ 28\,274 \\ 314 \\ 126 \\ 12 \\ \hline 60{\cdot}142 \end{array}$$

The correct answer is 60·1420648897.

When any number occurs frequently, it is convenient to make once for all a table of its multiples from 1 to 9, by adding the number to itself eight times. These multiples have then to be simply added, the decimal point being moved as required.

The multiples of π.

1.	3·1416
2.	6·2832
3.	9·4248
4.	12·5664
5.	15·7080
6.	18·8496
7.	21·9911
8.	25·1327
9.	28·2743

Thus, to find the circumference of a circle in metres the diameter of which is one yard (=·91438 metre),

3·1416 × ·91438.
·9............ 2·82743
·01........... ·03142
·004......... ·01257
·0003........ ·00094
·00008...... ·00025
2·87261 metres.

(3) DIVISION.

(i) A number is divisible by 2, 4, or 8, when the number formed by the last one, two, or three figures on the right is divisible by 2, 4, or 8 respectively.

(ii) Every number ending with 5 or 0 is divisible by 5 or 10 respectively.

(iii) Every number is divisible by 3 or 9, when the sum of the digits is divisible by 3 or 9 respectively.

(iv) A number is divisible by 11, when the difference between the sum of the figures in the odd places, and the sum of those in the even places is divisible by 11, or is zero.

The division of decimals may be shortened as follows :—

Make the number of decimal places equal in the divisor and in the dividend by annexing ciphers or the next figures of a recurring period. Divide in the ordinary way, but instead of bringing down ciphers cut off a figure from the divisor, remembering to carry from the multiple of the figure cut off.

$$\frac{3\cdot14159}{\cdot914383}$$

```
914383)3141590(3·43575
       2743149
       -------
        398441
        365753
        ------
         32688
         27431
         -----
          5257
          4572
          ----
           685
           640
           ---
            45
            45
            --
```

$$\frac{\cdot079085}{\cdot83497}$$

```
834970)790850(·094716
       751473
       ------
        39377
        33399
        -----
         5978
         5845
         ----
          133
           83
           --
           50
           50
           --
```

(4). PROPORTION.

The simple form of proportion usually required in chemical sums, is treated of under the name of 'Rule of Three,' and can be dealt with without making use of the signs of proportion.

Thus if 100 lbs. of mercury form 108 lbs. of mercuric oxide, how much oxide will be formed by 80 lbs. of mercury?

Since 100 lbs. of mercury form 108 lbs. of mercuric oxide,

1 lb. „ „ forms $\frac{108}{100}$ „ „

and 80 lbs. „ „ form $\frac{108}{100} \times 80 = 86\cdot4$ lbs. of mercuric oxide.

*In comparing two quantities of the same kind of thing expressed in the same denomination, the number of times that one is of the other is called the ratio of that one to that other and is written $a : b$ or $\frac{a}{b}$.

When two ratios are equal the four numbers form a proportion, which is written $a : b :: c : d$, or $a : b = c : d$.

In any proportion the product of the extremes is equal to the product of the means $ad = bc$. Hence if three terms are given in a proportion the fourth can be found,

$$a = \frac{bc}{d}, \text{ or } d = \frac{bc}{a}.$$

Thus, if 100 lbs. of mercury form 108 lbs. of mercuric oxide, how much oxide will be formed by 80 lbs. of mercury?

$$100 : 80 :: 108 : ? \textit{ Ans.} \text{ (or } x\text{)}.$$

$$x = \frac{108 \times 80}{100} = 86{\cdot}4 \text{ lbs. mercuric oxide.}$$

Since

$$\frac{a}{b} = \frac{c}{d},$$

$$\frac{a}{b} \pm 1 = \frac{c}{d} \pm 1,$$

$$\frac{a \pm b}{b} = \frac{c \pm d}{d};$$

or

$$a \pm b : b :: c \pm d : d.$$

Thus, if

$$a : 5 :: 12 : 4,$$

$$a = \frac{60}{4} = 15.$$

And also
$$a-5 : 5 :: 8 : 4,$$
$$a-5=\frac{40}{4},$$
$$a=15;$$
or
$$a+5 : 5 :: 16 : 4,$$
$$a+5=\frac{80}{4},$$
$$a=15.$$

*(5) SQUARE ROOT.

(i) Commencing with the unit figure cut off periods of two figures each in both directions. $\dot{3}6\dot{5}\cdot3\dot{6}5\dot{0}$.

(ii) The first figure of the required root will be the square root of the left-hand period, or of the greatest square contained in it.

(iii) Subtract the square of this figure from the first period; and to the remainder annex the next period for dividend; and for part of the divisor double the portion of the root already obtained.

(iv) Try how often this part of the divisor is contained in the dividend wanting the last figure, and annex the figure thus found to the parts of the root and divisor already found.

(v) Then multiply and subtract as in division, to the remainder bring down the next period and proceed as before.

(vi) When all the whole numbers have been used, proceed to find decimals, the period consisting of two decimal figures or of two ciphers.

Thus, to find $\sqrt{365}$,

```
          365(19·1049
          1
       29)265
          261
      381)  400
            381
    38204)   190000
             152816
     382089)3718400
            3438801
     382098)279599
```

If the answer be required to many decimal places, the working becomes laborious, but may be shortened as follows:—

Find half or one more than half the required figures by the above rules, and then annexing one figure instead of two proceed according to the contracted method of dividing decimals.

To continue the $\sqrt{365}$ found above:—

```
382098)2795990(73174
       2674691
        121299
        114630
          6669
          3821
          2848
          2675
           173
           153
            20
```

Hence $\sqrt{365} = 19·104973174$.

*The square root of a number, which is nearly a perfect square, may be approximately found as follows:—

If a be the root of the perfect square, and $a \pm b$ be the root of the given number N,

$$N = (a \pm b)^2 = a^2 \pm 2ab + b^2;$$

but if a^2 is nearly equal to N, b is so small that b^2 may be neglected.

Hence $$\pm b = \frac{N - a^2}{2a}.$$

Thus, to find $\sqrt{17}$,

$$a = 4,$$

$$b = \frac{17 - 16}{8} = \cdot 125;$$

$$\therefore \sqrt{17} = 4\cdot 125 \text{ instead of } 4\cdot 1231.$$

Again, to find $\sqrt{1300}$,

$$36^2 = 1296,$$

$$b = \frac{1300 - 1296}{2 \times 36} = \frac{4}{2 \times 36} = \frac{1}{18};$$

$$\therefore \sqrt{1300} = 36\cdot 05.$$

*(6) CONTINUED FRACTIONS.

It sometimes happens in finding the formula from the percentage composition of a substance (Sect. 27) that it is required to reduce the fraction representing the ratio of these results to its lowest terms, and then to find another fraction in lower terms nearly representing this ratio, the difference being due to experimental error.

The only form of continued fractions required in chemistry is the one in which every denominator is a whole number with a fraction annexed, which fraction has also for its denominator a whole number with a fraction and so on, every numerator being 1.

To convert a fraction into a continued one, divide the greater term by the less, the less by the remainder and so on, as in finding the greatest common measure; the quotients will be the denominators of the several fractions in the continued fraction, the numerator of each being 1.

Thus, to express $\frac{1{\cdot}41421}{1}$ as a continued fraction,

100000)141421(1
100000
41421)100000(2
82842
17158)41421(2
34316
7105)17158(2
14210
2948)7105(2
5896
1209)2948(2
2418
530)1209(2
&c.

$$1+\frac{1}{2}+\frac{1}{2}+\frac{1}{2}+\frac{1}{2}+\frac{1}{2}+\frac{1}{2}\ \text{\&c.}$$

The successive convergents which can be made from this continued fraction are

$$1,\quad 1\tfrac{1}{2},\quad 1\tfrac{2}{5},\quad 1\tfrac{5}{12},\quad 1\tfrac{12}{29},\quad 1\tfrac{29}{70},$$

which are alternately smaller and larger than the original number, to which also each successive convergent more nearly approximates.

To find the series of converging fractions from the quotients obtained as above.

Write the several quotients in a line, take the first quotient as the numerator and 1 as the denominator of the first fraction, which is set below the second quotient. Then for the second fraction, multiply both the terms of the first by the quotient which stands above it and add 1 to the numerator, the result is the second fraction which is set below the third quotient. To find the succeeding fractions, multiply the terms of each fraction, when found, by the quotient which stands above it, and to the products add separately the terms of the preceding fraction. Thus the convergents corresponding to the quotients

$$\begin{array}{lcccccccc} & 1 & 4 & 2 & 1 & 2 & 1 & 4 & \\ \text{are} & & \frac{1}{1} & \frac{5}{4} & \frac{11}{9} & \frac{16}{13} & \frac{43}{35} & \frac{59}{48} & \frac{279}{227}. \end{array}$$

(7) SYSTEMS OF MEASURES.

(i) The English System.

Measures of Length.

The Imperial Standard yard is the distance between the centres of two gold plugs in a bronze bar, when it is at the temperature of 62° F.

1 inch

12 inches = 1 foot.

36 inches = 3 feet = 1 yard.

63360 inches = 5280 feet = 1760 yards = 1 statute mile.

73036·8 inches = 6086·4 feet = 2028·8 yards = 1·152 miles
= 1 geographical mile or knot = 1000 fathoms.

A geographical mile is the mean length of one minute of longitude at the Equator.

The polar axis of the Earth is nearly $5{\cdot}005 \times 10^8$ inches in length.

Measures of area or surface.

1 square inch.

144 sq. ins. = 1 square foot.

1296 sq. ins. = 9 sq. ft. = 1 sq. yard.

43560 sq. ft. = 4840 sq. yds. = 1 acre.

27878400 sq. ft. = 3097600 sq. yds. = 623·7 ac. = 1 sq. mile.

Measures of volume or capacity.

1 cubic inch.

34·64 cub. ins. = 1 pint.

277·123 cub. ins. = 8 pts. = 1 gallon
= 0·160372 cub. foot.

1728 cub. ins. = 49·884 pts. = 6·314 gals. = 1 cub. ft.

46656 cub. ins. = 1346·9 pts. = 168·36 gals.
= 27 cub. ft. = 1 cub. yard.

5451776000 cub. yds. = 1 cubic mile.

A gallon of water at 62° F. weighs 10 lbs. or 70000 grains.

A cubic inch of water at 39° F. weighs 252·88 grains.

A cubic foot of water at 39° F. weighs 62·425 lbs. or 998·8 ozs.

A pound of water occupies ·0162 of a cubic foot.

1000000 volumes of water at 39° F. become 1001118 volumes at 62° F.

Measures of Mass.

The Imperial Standard pound avoirdupois is the mass in vacuo of a certain piece of platinum.

1 grain avoirdupois and Troy.
437·5 grns. = 1 ounce avoirdupois (oz.).
7000 grns. = 16 ozs. = 1 pound avoirdupois (lb.).
784000 grns. = 1792 ozs. = 112 lbs. = 1 hundredweight (cwt.).
15680000 grns. = 35840 ozs. = 2240 lbs. = 20 cwts. = 1 ton.
100 lbs. = 1 cental.

480 grains = 1 ounce Troy.
5760 grains = 1 ounces Troy = 12 pound Troy.
1 ounce Troy = 1·097 ozs. avoirdupois.
1 lb. avoirdupois = 1·215 pounds Troy.

1 ton of water occupies 224 gallons or 35·88 cubic feet.

(ii) THE METRIC SYSTEM.

In the metric system all the measures are multiplied by 10 and its powers, multiples being shown by prefixing a Greek numeral; and also divided by 10 and its powers, submultiples being shown by prefixing a Latin numeral.

Measures of Length.

The metre is the length of a certain bar of platinum at 0° C.

1 millimetre.
10 m.m. = 1 centimetre.
100 m.m. = 10 c.m. = 1 decimetre.
1000 m.m. = 100 c.m. = 10 d.m. = 1 **metre.**
10000 m.m. = 1000 c.m. = 100 d.m. = 10 m.
= 1 dekametre.

100000 m.m. = 10000 c.m. = 1000 d.m. = 100 m.
= 10 dekam. = 1 hectometre.

1000000 m.m. = 100000 c.m. = 10000 d.m. = 1000 m.
= 100 dekam. = 10 hectom. = 1 kilometre.

The metre was constructed to be the $\frac{1}{10000000}$ of the quadrant of the globe passing through Paris. According to the best modern results however this quadrant really measures 10001472·5 times the length of the standard metre, which is preserved at Paris.

Measures of Area or Surface.

1 square millimetre.
100 sq. m.m. = 1 square centimetre.
10000 sq. m.m. = 100 sq. cm. = 1 sq. decimetre.
1000000 sq. m.m. = 10000 sq. cm. = 100 sq. dm.
= 1 sq. metre or centiare.
100 square metres or centiares = 1 **are**
1000000 sq. metres = 10000 ares = 1 square kilometre.

Measures of Volume or Capacity.

1 cubic centimetre (c.c.).
1000 c.c. = 1 cubic decimetre (a litre).
1000000 c.c. = 1000 litres = 1 cubic metre (a stere).

Measures of Mass.

A kilogram is the mass of a certain piece of platinum in vacuo.

1 milligram.
10 m.g. = 1 centigram.
100 m.g. = 10 c.g. = 1 decigram.
1000 m.g. = 100 c.g. = 10 d.g. = 1 gram.

1000 grams = 1 kilogram.
1000000 grams = 1000 kilos. = 1 tonne.

The kilogram was intended to be the mass of one cubic decimetre of water measured at 4° C. But it is found that the mass of 1 c.c. of water at 4° C. is 1·000013 grams.

For the conversion of English to Metric and of Metric to English measures see Table II.

*(iii) THE C.G.S. SYSTEM.

Nearly all the quantities, with which physical science deals, can be expressed in terms of three fundamental units, of which the most convenient are :—

a definite length—the Centimetre.
a definite mass—the Gram.
a definite time—the Second.

Surface is expressed in square centimetres, and volume in cubic centimetres. The gram, the unit of mass, is very nearly the mass of the unit-volume of water at 4° C.

The C.G.S. unit of force is the *dyne*. It is the force, which acting on a gram for a second, generates in it a velocity of 1 centimetre per second.

Thus, if a body falls in vacuo at Greenwich for 1 second, the velocity is found to be at the rate of 981·17 centimetres per second. Or the force exerted upon a body at Greenwich, by the attraction of the earth is $g = 981{\cdot}17$ dynes. At Paris $g = 980{\cdot}94$ dynes.

The C.G.S. unit of work is called the *erg*. It is the amount of work done by a dyne working through the distance of 1 centimetre.

The C.G.S. unit of energy is also the erg, since energy is measured by the amount of work which it represents.

If a body the mass of which is m grams fall through a distance h centimetres; the working force is the action of gravity upon the mass of the body $= gm$ dynes, which, multiplied by h the distance passed through, gives mgh ergs as the work done. But the velocity acquired is such that $v^2 = 2gh$. Hence $mgh = \frac{1}{2}mv^2$.

The kinetic energy of a mass of m grams with the velocity of v centimetres per second is $\frac{1}{2}mv^2$ ergs.

In cases in which great accuracy is not required, it is usual to consider gravity as a force constant at all positions on the earth's surface, and to reckon work by a mass lifted through a certain distance in opposition to gravity.

Thus a kilogram-metre is the work done in lifting a kilogram through a metre in opposition to gravity.

$$\text{A kilogram-metre} = 100000 \times g \text{ ergs.}$$

A foot-pound is the work done in lifting a pound through a foot in opposition to gravity.

$$\text{A foot-pound} = 13825 \times g \text{ ergs.}$$

A horse-power is the power of doing work at the rate of 33000 foot-pounds per minute or 550 foot-pounds per second, it is equal to $7{\cdot}46 \times 10^9$ ergs per second.

Since only one unit for each measure is used in the C.G.S. system, the easy and rapid expression of large multiples and of small sub-multiples is a matter of great importance.

The prefix micro- is used to express division by a million; a microdyne is the millionth of a dyne: the prefix mega- or megal- is used to denote multiplication by a million; a megalerg is a million ergs.

In expressing small or large multiples of the unit in figures it is most convenient to write them as one figure of whole numbers, followed by decimals, and multiplied by the requisite negative or positive power of 10.

Thus 324,000,000,000 is written $3{\cdot}24 \times 10^{11}$,
and ·000 003 24 as $3{\cdot}24 \times 10^{-6}$.

The power of 10 used is the characteristic of the common logarithm of the expression.

These multiples of 10 are easily expressed in words, thus 10^9 grams is spoken of as a gram-nine, and 10^{-9} grams is spoken of as a ninth-gram.

The prefix mega- is equivalent to the affix -six, and the prefix micro- to the prefix sixth-.

(iv) MEASURES OF TIME.

The sidereal day is the period in which the earth turns once on its axis, and is equal to 86,164 mean solar seconds.

The earth goes round the sun in one tropical year of 365·24224 mean solar days or 31,556,929 mean solar seconds.

1 second.
60 seconds = 1 minute.
3600 seconds = 60 minutes = 1 hour.
86400 seconds = 1440 minutes = 24 hours = 1 mean solar day.
1 mean solar day = 1·00273791 sidereal days.

(v) MEASURES OF ANGLES.

If a straight line be kept constantly in a plane with one end centered at a fixed point, and be then caused to revolve with a motion like the hand of a clock, it moves through an angular space called *a round* in making one revolution.

One-fourth of a round is called a quarter-round or *right-angle.* (Cf. Euc. Bk. I. Defin. X.)

1 second.
$60'' = 1$ minute.
$3600'' = 60' = 1$ degree.
$324000'' = 5400' = 90^\circ = 1$ right-angle.
$1296000'' = 21600' = 360^\circ = 4$ rts. $= 1$ round.

A *radian* is the angle between two radii of a circle, which comprise between them an arc of the circle equal in length to the radius.

1 radian $= 57·29578^\circ = 3437·747' = 206,264·8''$ nearly,
or $180^\circ = 3·14159265$ &c. radians.
$1^\circ = ·0174533$ radian.

(8) MENSURATION.

$\pi = 3{\cdot}1416 = \frac{22}{7}$ nearly.

Plane Areas.

1.	Square, side a.	$A = a^2$.
2.	Triangle, base c, perpend. d.	$A = \frac{1}{2}cd$.
3.	Rectangle, sides ab.	$A = ab$.
4.	Circle, radius r.	$A = \pi r^2$.
5.	Ellipse, semiaxes ab.	$A = \pi ab$.

Surfaces.

1.	Cube, edge a.	$S = 6a^2$.
2.	Sphere, radius r.	$S = 4\pi r^2$.
3.	Cylinder, radius r height h.	$S = 2\pi r(h + r)$.
4.	Spherical segment, height h.	$S = 2\pi rh$.

Volumes.

1.	Cube, edge a.	$V = a^3$.
2.	Rectangular parallelopiped edges a, b, c.	$V = abc$.
3.	Sphere, radius r.	$V = \frac{4}{3}\pi r^3$.
4.	Spheroid, radii a, b, b.	$V = \frac{4}{3}\pi ab^2$.
5.	Cylinder or prism.	V = area of base × height.
6.	Cone or pyramid.	V = $\frac{1}{3}$ area of base × height.

PHYSICS AND CHEMISTRY.

(9) MASS, VOLUME, DENSITY AND WEIGHT.

The mass of, or quantity of matter in, a body remains constant so long as nothing is added to or taken from the body, and is proportional to the volume and density conjointly. Two bodies are of equal mass, if equal forces applied to them produce in equal times equal changes of velocity.

The density (Δ) of a body is measured by the number of units of mass contained in the unit of volume of it.

Hence in the metric system the density of a solid or liquid is measured by the number of grams in one cubic centimetre of it, or by the number of kilograms in one litre of it.

$$D=\frac{M}{V}. \quad V=\frac{M}{D}. \quad DV=M.$$

Thus 1000 c.c. of copper Δ 9, contain $1000 \times 9 = 9000$ grams, and 1000 grams of copper occupy $\frac{1000}{9} = 111{\cdot}1$ c.c.

Since 1 c.c. of water at the temperature of 4° C. contains 1·000013 grams, the density of a solid or liquid is measured very nearly by the number of times it is heavier or lighter than an equal volume of water at the temperature of 4° C.

Thus cast-lead is 11·35 times heavier than water, and its true density is $11{\cdot}35 \times 1{\cdot}000013 = 11{\cdot}35014755$.

This correction is so small that it may be neglected in all ordinary cases.

* In the English system if a cubic foot be taken as the unit of volume, the density of a body is measured by the

number of pounds in one cubic foot of it; and the number of times a body is heavier or lighter than an equal volume of water at 62°F. is spoken of as its specific gravity. Since a cubic foot of water at 4°C. weighs 62·425 lbs., the density of a substance is nearly 62·4 times its specific gravity.

Thus, the specific gravity of mercury is 13·55, but its density is 848·75.

The mass of a body is in practice usually measured by its weight, that is, by the attraction of the earth upon it, which is equal to the mass of the body multiplied by g, the velocity which it would acquire by falling freely in vacuo for a second under the influence of the attraction of the earth.

$$W = Mg \text{ (where } g = 981 \text{ c.m. in London).}$$

Since the force of gravity, though always the same at the same place, increases in passing from the Equator to the Pole, because in the latter case the body is nearer the centre of the earth, and also the centrifugal force acting upon it becomes less, the weight of a body varies according to its geographical position and to its distance above the sea-level.

If then masses at different places were compared by estimating the weights of the bodies by means of a spring-balance, a correction for the difference of the force of gravity would have to be introduced. But in chemistry masses are usually compared by the number of standard pieces of metal (weights) on which the earth exercises an equal attraction. Hence in a balance masses and not weights are in reality estimated.

The word weight is often wrongly used when mass is really meant, e.g. a gram or a pound is a unit of mass and not a unit of weight.

The Chemical Balance, by which the equality of masses is determined, consists of a lever with equal arms, hence when the instrument is in equilibrium the mass in one pan is equal to the mass in the other pan.

In very exact experiments the chance of error arising from any inequality in the length of the arms may be obviated by two methods.

(i) In the method of counterpoise, the substance is placed in one pan, and shot, sand, &c. are placed in the other pan to counterpoise it. The substance is then removed, and weights are put into the pan to balance the counterpoise.

(ii) In the method of double-weighing, the substance is placed in one pan and balanced by weights, W_1 in the other. The substance is then changed into the other pan, and balanced by weights W_2 in the first pan. If a, b be the lengths of the arms of the balance and x the true mass of the substance:—

$$x \times a = b \times W_1,$$

and

$$W_2 \times a = b \times x,$$

or

$$\frac{x}{W_2} = \frac{W_1}{x},$$

$$\therefore x^2 = W_1 W_2,$$

and

$$x = \sqrt{W_1 W_2};$$

if the difference between W_1 and W_2 be small,

$$x = \tfrac{1}{2}(W_1 + W_2) \text{ nearly.}$$

Thus a crucible is found to weigh 19·76 grams in one pan, and 19·74 grams in the other, find its true mass.

$x = \sqrt{19{\cdot}76 \times 19{\cdot}74} = 19{\cdot}74999$, or very nearly 19·75 grams.

From the relations between volume, density, and mass given above, many important questions connected with changes in volume and density, when metals are alloyed together, or when solids dissolve in water, can be solved directly.

If metals having volumes V_1, V_2, V_3, &c. and densities Δ_1, Δ_2, Δ_3 are fused together to form an alloy having the volume V_x and the density Δ_x,

$$V_1\Delta_1 + V_2\Delta_2 + V_3\Delta_3 + \&c. = V_x\Delta_x.$$

Again, suppose that the masses of the metals mixed are M_1, M_2, M_3 and the mass of the alloy formed is M_x, if no permanent change of volume takes place,

$$\frac{M_1}{\Delta_1} + \frac{M_2}{\Delta_2} + \frac{M_3}{\Delta_3} + \&c. = \frac{M_x}{\Delta_x}.$$

Thus, the native alloy of mercury ($\Delta 13{\cdot}59$) and gold ($\Delta 19{\cdot}3$) ($Hg_3\ Au_2$) consists of 600 parts of mercury alloyed with 393·2 parts of gold, find its density if no contraction takes place.

$$\frac{600}{13{\cdot}59} + \frac{393{\cdot}2}{19{\cdot}3} = \frac{993{\cdot}2}{x}$$

$$\therefore\ x = 15{\cdot}4.$$

The density is found by experiment to be 15·47, hence a small contraction takes place during the reaction.

When solids dissolve in water the volume of the solution is usually less than the volume of the water and of the solid together.

When 20 grams of nitre ($\Delta 2{\cdot}12$) are dissolved in 80 grams of water the solution has the density 1·136, what would the volume have been if no contraction had taken place, and what is it?

$$\frac{20}{2{\cdot}12} + \frac{80}{1} = 9{\cdot}56 + 80 = 89{\cdot}56 \text{ c.c.}$$

if there had been no contraction.

But $\frac{100}{1{\cdot}136} = 88{\cdot}02$ c.c. is the volume of the solution.

(10) FROM THE FORMULA OF A SUBSTANCE TO FIND ITS MOLECULAR WEIGHT AND PERCENTAGE COMPOSITION.

The Atomic weight of an element is the number of times, which the smallest portion of that element, that can take part in a chemical change, is heavier than the smallest portion of hydrogen, that can take part in a chemical change. An atom of hydrogen is supposed to weigh $3{\cdot}5 \times 10^{-24}$ grams.

These atomic weights are expressed by symbols, which are usually the first letters or first two letters of the English or Latin name of the element.

Thus H	represents the	hydrogen-atom	weighing	1
O	,,	oxygen-atom	,,	16
Fe	,,	iron-atom	,,	56

The molecular weight of an element or compound is the number of times which the smallest portion of that element or compound, that can exist in the free state, is heavier than the atom of hydrogen.

Comparatively few of the molecular weights of the elements have yet been determined, they are usually multiples of the atomic weights by 2, but in some instances by 1, 4, or 6.

Thus

$H_2 = 1 \times 2 = 2$	is the	molecular	weight	of	Hydrogen.
$O_2 = 16 \times 2 = 32$	,,	,,	,,		Oxygen.
$N_2 = 14 \times 2 = 28$	,,	,,	,,		Nitrogen.
$Cl_2 = 35{\cdot}5 \times 2 = 71$	,,	,,	,,		Chlorine.
$Br_2 = 80 \times 2 = 160$	,,	,,	,,		Bromine.
$I_2 = 127 \times 2 = 254$	,,	,,	,,		Iodine.

$K_2 = 39{\cdot}1 \times 2 = 78{\cdot}2$ is the molecular weight of Potassium.
$Hg = 200 \times 1 = 200$ „ „ „ Mercury.
$Cd = 112 \times 1 = 112$ „ „ „ Cadmium.
$P_4 = 31 \times 4 = 124$ „ „ „ Phosphorus.
$As_4 = 75 \times 4 = 300$ „ „ „ Arsenic.
$S_6 = 32 \times 6 = 192$ „ „ „ Sulphur (below 600° C.).
$S_2 = 32 \times 2 = 64$ „ „ „ Sulphur (above 1000° C.).

The molecular weight of a compound is the *sum* of the atomic weights of all the atoms of the elements which compose it.

Thus the molecular weight of hydrogen chloride HCl is

$$1 + 35{\cdot}5 = 36{\cdot}5.$$

The molecular weight of water H_2O is

$$1 \times 2 + 16 = 18.$$

The molecular weight of hydrogen sulphate H_2SO_4 is

$$1 \times 2 + 32 + 16 \times 4 = 98.$$

From the symbol, also, the percentage composition, or number of grams of each element in 100 grams of a compound, may be readily calculated.

The name of each element present being written in a column, and opposite to each the multiple of its atomic weight which is present in the compound, on adding these numbers together the molecular weight of the compound is obtained. Since the numbers opposite to each element express the number of parts of that element present in the molecular weight of the compound, on multiplying each of these numbers by 100 and dividing by the molecular weight, parts in 100 or percentages are obtained.

Thus, to find the percentage composition of carbon dioxide CO_2,

$$\text{Carbon} \quad C = 12 \times \frac{100}{44} = 27{\cdot}27.$$

$$\text{Oxygen} \quad O_2 = \frac{32}{44} \times \frac{100}{44} = \frac{72{\cdot}73}{100{\cdot}00}.$$

For since

44 parts of carbon dioxide contain 12 parts of carbon

1 part „ „ contains $\frac{12}{44}$ „ „

100 parts „ „ contain $\frac{12 \times 100}{44}$ „ „

(11) FROM AN EQUATION TO CALCULATE A MASS.

A chemical equation expresses that certain substances present in definite proportions react upon one another to form certain other substances also in definite proportion. Since matter is indestructible, the sum of the masses or molecular weights of the substances before the change must be equal to the sum of the masses or molecular weights of the substances after the change.

Thus $Mg + O = MgO$ expresses that 24 parts of magnesium react with 16 parts of oxygen to form $24 + 16$ or 40 parts of magnesium oxide. And if it be required to find how many grams of magnesium oxide are formed on burning 10 grams of magnesium, the equation shews that

24 grams of magnesium form 40 grams of magnesium oxide,

∴ 1 gram „ „ forms $\frac{40}{24}$ „ „ „

& 10 grams „ „ form $\frac{40 \times 10}{24} = 16{\cdot}\dot{6}$ „ „

The same result may be reached with still greater rapidity by the use of simple proportion.

Find the multiples of the atomic or molecular weights of the substances given and asked in the equation, and make the proportion :—

The molecular weight of substance given : the molecular weight of substance asked :: the real mass of substance given : the real mass of substance asked.

Thus, to find how many grams of sodium sulphate can be obtained from 100 grams of sodium hydrate,

$$\begin{array}{ll} 2HNaO + H_2SO_4 = 2H_2O + & Na_2SO_4. \\ 2 \times 40 & \quad 142 \end{array}$$

$$2 \times 40 : 142 :: 100 : x$$

$$x = \frac{14200}{80} = 177{\cdot}5 \text{ grams.}$$

* (12) FLUID PRESSURE.

When the action of pressure upon fluids is investigated, it is found that some fluids, e. g. water and mercury, decrease in volume very slightly even under a greatly increased pressure; such fluids are roughly said to be incompressible: but other fluids, e. g. air and hydrogen, are found to decrease in volume considerably under increased pressure; such fluids are said to be compressible.

Fluids, when compressed, transmit the pressure equally in all directions, and hence any substance immersed in a fluid or floating upon it is buoyed up by a force equal to the weight of the fluid displaced.

Two important consequences of this fact may be noted :—

(i) Suppose a body of known mass M floats in a liquid of density Δ, with the volume V immersed,

$$Mg = V\Delta g,$$

$$\Delta = \frac{M}{V};$$

thus, the mass of an hydrometer divided by the volume of the immersed portion gives the density of the liquid in which it floats.

(ii) When substances are weighed in a balance, they are usually immersed in air, and hence they apparently weigh less than they really do by a weight equal to that of the air displaced. The weights are also affected by the same cause.

Hence, if V_s be the volume of the substance in c. c., V_w that of the weights, and a the mass of 1 c. c. of air under the conditions of experiment, the real mass of the substance is equal to the mass of the weights

$$+ a\,(V_s - V_w),$$

where $$a = \frac{0{\cdot}001293 \times H}{(1 + {\cdot}00367t) \times 760} \text{ nearly.}$$

The total normal pressure on a surface of area A immersed in an incompressible fluid of density Δ is

$$P = A \,.\, \Delta \,.\, g \,.\, \bar{z},$$

where $\bar{z}$ is the depth of the centre of gravity of the surface below the surface of the fluid.

Thus, to find the pressure on a surface of 1 sq. c.m. immersed with its centre of gravity 76 c.m. below the surface of mercury Δ 13·596,

$$P = 1 \times 13{\cdot}596 \times 76 \times 981 = 1033{\cdot}3 \times 981 \text{ grams.}$$

In the case of gas or vapour the pressure may be measured in a variety of ways, e.g. by the elasticity of a thin sheet of metal as in the aneroid barometer, by a lever and weight as in the safety-valve &c., but in accurate experiments it is preferable to measure the pressure by finding the height of the column of a liquid of known density, generally mercury, which the pressure of the gas will sustain.

(13) THE BAROMETER.

The barometer in its most simple form consists of a tube about 1 c.m. wide, and 80 c.m. long, closed at one end, filled with mercury, and inverted in a vessel of mercury.

Since fluids transmit pressure equally in all directions, the pressure of the air on a portion of the surface of the mercury of area A in the vessel is equal to that of the column of mercury inside the tube the area of which is also A,

$$P = A \,.\, H \,.\, \Delta \,.\, g.$$

Taking A as 1 sq. c.m. and omitting g as being constant for the same place,

$$P = H \times 13{\cdot}596.$$

The standard pressure of the air, called an atmosphere, is taken as equal to that of a column of mercury 760 m.m. or 76 c.m. high.

In this case $P = 76 \times 13{\cdot}596 = 1033{\cdot}6$ grams on the square centimetre, or 14·7 lbs. on the square inch.

If two barometers under the same circumstances contain liquids of different densities,

$$h\delta = H\Delta,$$

$$h = \frac{H\Delta}{\delta}.$$

When the mercury (Δ 13·596) barometer stands at 720 m.m. how high will one of glycerine (δ 1·27) stand?

$$h = \frac{72 \times 13{\cdot}596}{1{\cdot}27} = 770{\cdot}8 \text{ c.m.}$$

* Since increase of temperature causes the mercury and the scale of the barometer to expand, a correction must be applied for any temperature t° C. If the reading on a brass scale is h m.m. the true reading is $H = h\,(1 - 0{\cdot}00016\,t)$.

The higher a barometer is carried from the sea-level the less is the action of gravity upon the mercury, and the shorter is the column of air above the mercury, hence for each metre that the place of observation is above the level of the sea, ·083 m.m. must be added to the observed height of the barometer, to reduce it to the true reading at the sea-level.

The difference in height in metres D between two places at the temperatures T° and t° Centigrade, where the mercury-barometer stands at H and h metres respectively, may be found by the formula,

$$D = 16000\left[1 + \frac{2\,(T+t)}{1000}\right]\frac{H-h}{H+h}.$$

(14) THE CHANGE IN VOLUME OF A MASS OF GAS PRODUCED BY A CHANGE IN PRESSURE.

Boyle's Law. The volume of a mass of gas varies inversely as the pressure upon it; or, the volume of a mass of gas multiplied by the pressure at any one time is equal to the volume of the same mass of gas multiplied by the pressure upon it at any other time;

$$VP = vp,$$

or

$$V = \frac{vp}{P}.$$

If the pressure upon 1000 c. c. of gas be increased from 400 m.m. to 800 m.m. what is the new volume?

$$V = \frac{1000 \times 400}{800} = 500 \text{ c. c.}$$

250 c. c. of gas under pressure of 742 m.m. have the pressure increased to 760 m.m. What is the new volume?

$$V = \frac{250 \times 742}{760} = 244{\cdot}08 \text{ c. c.}$$

(15) TEMPERATURE AND THERMOMETERS.

The temperature or hotness of a body is the energy with which the heat in that body tends to transfer itself to other bodies. Temperature is usually measured by thermometers, which are generally inclosed volumes of air or mercury from the expansion of which the temperature is determined.

In every case two 'fixed points' are taken, the melting-point of ice, and the boiling-point of water under a pressure of 760 m.m. of mercury.

The difference in temperature between these two points is divided into a number of equal degrees and a similar graduation is carried above and below the fixed points.

Three different scales are in use:—

	Melting of ice.	Interval.	Boiling-point.
The Centigrade scale	0° C.	100° C.	100° C.
Fahrenheit's scale	32° F.	180° F.	212° F.
Réaumur's scale	0° R.	80° R.	80° R.

Since the difference between the fixed points is the same in each case,

$$100^\circ \text{C.} = 180^\circ \text{F.} = 80^\circ \text{R.},$$

or

$$5^\circ \text{C.} = 9^\circ \text{F.} = 4^\circ \text{R.}$$

Hence any given number of degrees a on one scale can be expressed on another scale by the following formulæ:—

$$\frac{(a^\circ \text{F.} - 32)\,5}{9} = x^\circ \text{C.}, \qquad \frac{(a^\circ \text{F.} - 32)\,4}{9} = x^\circ \text{R.},$$

$$\frac{a^\circ \text{C.} \times 9}{5} + 32 = x^\circ \text{F.}, \qquad \frac{a^\circ \text{C.} \times 4}{5} = x^\circ \text{R.},$$

$$\frac{a^\circ \text{R.} \times 9}{4} + 32 = x^\circ \text{F.}, \qquad \frac{a^\circ \text{R.} \times 5}{4} = x^\circ \text{C.}$$

Thus, to find what temperature Centigrade is equal to 113° F.,

$$\frac{(113^\circ \text{F.} - 32) \times 5}{9} = 45^\circ \text{C.};$$

and what temperature Fahrenheit is equal to -32° R.,

$$\frac{-32^\circ \text{R.} \times 9}{4} + 32 = -40^\circ \text{F.}$$

There are reasons for supposing that -273° C. is the lowest possible temperature; hence it is called the absolute zero, and absolute temperatures are measured from it as Centigrade temperatures are measured from the melting-point of ice.

Any temperature expressed on the Centigrade scale is converted into the absolute scale by adding 273 to it.

Thus -13° C. is $-13 + 273 = 260^\circ$ on the absolute scale.

(16) EXPANSION BY HEAT.

Solids and liquids usually increase in volume when heated and decrease in volume when cooled, but the change is so small, that in ordinary chemical experiments it may be neglected.

Thus 5550 volumes of mercury at 0° C. increase by one volume for every 1° C. through which they are heated, becoming $5550 + 100 = 5650$ volumes at 100° C.

The expansion of gases however is so considerable that a change of a very few degrees may affect an experimental result.

Gay Lussac's Law. When 273 volumes of a gas at 0° C. are heated, they increase by one volume for every 1° C. through which they are heated.

Thus

273 volumes of gas at 0° C. become at 1° C. $273 + 1$ volumes,
273 „ „ „ „ „ 2° C. $273 + 2$ „
273 „ „ „ „ „ 3° C. $273 + 3$ „
273 „ „ „ „ „ t° C. $273 + t$ „
273 „ „ „ „ „ T° C. $273 + T$ „

where t and T express any number of degrees on the Centigrade scale.

Hence $273 + t$ volumes of gas at t° C. become at T° C.
$273 + T$ volumes,

or 1 volume at t° C. becomes at T° C. $\frac{273 + T}{273 + t}$ volumes,

and v volumes at t° C. become at T° C. $v \times \frac{273 + T}{273 + t}$ volumes;

which, if V stand for the volume of the gas after a change of temperature from t° C. to T° C., is usually written

$$V = \frac{v(273 + T)}{273 + t}.$$

To find the new volume if 1000 c.c. of gas are heated from 17° C. to 27° C.

$$V = \frac{1000(273 + 27)}{273 + 17} = \frac{1000 \times 300}{290} = 1034{\cdot}8 \text{ c.c.}$$

If 1000 c.c. of gas at -23° C. are heated to 27° C., find the new volume.

$$V = \frac{1000(273 + 27)}{273 - 23} = \frac{1000 \times 300}{250} = 1200 \text{ c.c.}$$

If the pressure on the gas as well as its temperature be changed, the above formula must be combined with the one given in (**14**).

$$V = \frac{v(273 + T)}{273 + t} \times \frac{p}{P}.$$

If 500 c.c. of gas are cooled from 39° C. to 13 C., the pressure being decreased from 800 m.m. to 300 m.m., find the new volume.

$$V = \frac{500(273 + 13)}{273 + 39} \times \frac{800}{300}$$

$$= \frac{500 \times (286) \times 800}{(312) \times 300} = 1222{\cdot}2 \text{ c.c.}$$

*In certain cases the fraction $\frac{11}{3000}$, which is at least equally correct, is more convenient for calculation than $\frac{1}{273}$.

Then
$$V = \frac{v\,(3000 + 11T)}{3000 + 11t}.$$

Thus, to find the new volume if 1000 c.c. of gas are heated from 0° C. to 300° C.,

$$V = \frac{1000\,(3000 + 3300)}{3000} = 2100 \text{ c.c.}$$

In other cases, and especially when logarithms are used, it is more convenient to use formulæ containing decimal instead of vulgar fractions. Thus:—

1 volume of gas at 0° C.

when	heated to	1° C.	becomes	$1 + \cdot 00367 \times 1$ vols.
„	„	2° C.	„	$1 + \cdot 00367 \times 2$ „
„	„	3° C.	„	$1 + \cdot 00367 \times 3$ „
„	„	t° C.	„	$1 + \cdot 00367 \times t$ „
„	„	T° C.	„	$1 + \cdot 00367 \times T$ „

Hence
$$V = \frac{v\,(1 + \cdot 00367\,T)}{1 + \cdot 00367\,t}.$$

The fraction ·00367 is called the coefficient of expansion of a gas, and is frequently expressed by a.

(17) THE DENSITY OF GASES.

When the pressure on and temperature of a gas are not mentioned, it is supposed to be at 0° C. and 760 m.m. A gas under these conditions is said to be *normal*.

The formulæ given in this and the succeeding section only apply to normal gases; hence, when necessary, the gas under consideration must be rendered normal by using the formula :—

$$V=\frac{v\times 273}{273+t}\times\frac{p}{760}.$$

And conversely the volume found by these formulæ is normal and must be reduced to the required temperature and pressure by

$$V=\frac{v\,(273+T)}{273}\times\frac{760}{P}.$$

It has already been stated in (9) that the density of a substance is the mass of unit-volume of it, but in the case of gases the cubic centimetre and gram, which are used in the case of solids and liquids, are not convenient units.

In the case of gases, the litre = 1000 c.c. is taken as the unit of volume, and the mass of one litre of normal hydrogen, called a *crith* = ·0896 gram, is taken as the unit of mass.

The density of a gas then is the number of criths contained in one litre of it measured at 0° C. and 760 m.m.; or the number of times it is heavier than an equal volume of hydrogen.

Hence the mass in grams of a litre of any normal gas can be found by multiplying its density by ·0896.

Thus the density of carbon monoxide being 14, a litre of carbon monoxide weighs 14 × ·0896 = 1·2544 grams.

It is found that with few exceptions the density of any elementary gas is expressed by the same number as its atomic weight, and that of any compound gas is expressed by the same number as half its molecular weight. Thus :—

Hydrogen H = 1. Density 1, or 1 litre weighs 1 crith.
Oxygen O = 16. Density 16, or 1 litre weighs 16 criths.
Nitrogen N = 14. Density 14, or 1 litre weighs 14 criths.
Ammonia NH_3 = 17. Density 8·5, or 1 litre weighs 8·5 criths.
Marsh gas CH_4 = 16. Density 8, or 1 litre weighs 8 criths.
Carbon dioxide CO_2 = 44. Density 22, or 1 litre weighs 22 criths.

If the density be doubled, or, in other words, if the unit of hydrogen be taken as 2 instead of 1, the double-density of almost every gas is expressed by the same number as its molecular weight.

The densities of gases used to be referred to air, which is 14·436 times as heavy as hydrogen. In such a case, to find the density referred to hydrogen, multiply the density referred to air by 14·436.

Thus sulphur dioxide is 2·22 times as heavy as air: find its density and molecular weight.

14·436 × 2·22 = 32·042 is the density referred to hydrogen,
and
32·042 × 2 = 64·084 is the molecular weight.

If the density of a gas referred to air is given, to find the mass of one litre of it, multiply the given density by 1·293, the mass in grams of one litre of normal air.

Thus carbon dioxide is 1·529 times as heavy as air, to find the mass of one litre of it

$$1·529 \times 1·293 = 1·977 \text{ grams.}$$

Conversely, if it be required to find the density referred to air from that referred to hydrogen, multiply the density referred to hydrogen by ·06926, the density of hydrogen referred to air.

Thus nitric oxide is 15 times as heavy as hydrogen: how many times is it heavier than air?

$$15 \times \cdot 06926 = 1 \cdot 0389.$$

Owing to their molecules being broken up by heat at temperatures but little above their boiling points, about fifteen substances form vapours having densities either half or two-thirds of the number obtained by halving their molecular weights. And in a few other cases the density of the vapour is expressed by the same number as the molecular weight.

The more important of these exceptions are :—

Mercury 100.
Cadmium 56.
Phosphorus 62.
Arsenic 150.
Nitric oxide 15.

Nitrogen tetroxide 23.
Arsenic trioxide 198.
Mercurous chloride 118.
Hydrogen sulphate 24·5.
Ammonium chloride 13·4.
Phosphorus pentachloride 52.
Chlorine trioxide 29·7.
Chlorine tetroxide 33·8.

(18) VOLUME AND MASS OF GASES.

It is found by experiment that 22·32 litres of any normal gas weigh a number of grams equal to the number expressing the molecular weight of the gas. Thus

22·32	litres of	hydrogen	($H_2 = 2$)	weigh	2	grams.
22·32	"	oxygen	($O_2 = 32$)	"	32	"
22·32	"	nitrogen	($N_2 = 28$)	"	28	"
22·32	"	chlorine	($Cl_2 = 71$)	"	71	"
22·32	"	ammonia	($NH_3 = 17$)	"	17	"
22·32	"	marsh-gas	($CH_4 = 16$)	"	16	"
22·32	"	carbon dioxide	($CO_2 = 44$)	"	44	"
22·32	"	cyanogen	($C_2N_2 = 52$)	"	52	"

This volume 22·32 litres is commonly spoken of as "two volumes" and expressed by the symbol □□.

If great accuracy is not required, the more convenient number 22·4 litres may be used instead of 22·32 litres.

Since 22·32 litres of any gas weigh its molecular weight in grams, a litre of any gas weighs its molecular weight in grams divided by 22·32, and one gram of any gas occupies 22·32 litres divided by its molecular weight.

Hence the mass in grams of any volume of a gas can be found by multiplying the number of litres of it by its molecular weight and dividing by 22·32.

Thus, to find the mass of 250 litres of chlorine ($Cl_2 = 71$),

$$\frac{250 \times 71}{22{\cdot}32} = 795{\cdot}25 \text{ grams.}$$

Conversely the volume in litres of any gas can be found by multiplying the number of grams of it by 22·32 and dividing by the molecular weight.

Thus, to find the volume of 225 grams of hydrogen sulphide ($H_2S = 34$),

$$\frac{225 \times 22{\cdot}32}{34} = 147{\cdot}7 \text{ litres.}$$

Find the mass of 80 litres of oxygen ($O_2 = 32$) measured at 52° C. and 740 m.m.

The gas must be reduced to 0° C. and 760 m.m.

$$\frac{80 \times 273}{273 + 52} \times \frac{740}{760} \times \frac{32}{22{\cdot}4} = \frac{8880}{95} = 93{\cdot}47 \text{ grams.}$$

What volume at 13° C. and 750 m.m. is occupied by 14·2 grams of chlorine ($Cl_2 = 71$)?

$$\frac{14{\cdot}2 \times 22{\cdot}4}{71} \times \frac{273 + 13}{273} \times \frac{760}{750} = \frac{1510{\cdot}08}{225} = 6{\cdot}71 \text{ litres.}$$

(19) EQUATION AND VOLUMES OF GASES.

When the volume of one gas is given and that of another gas is asked, since each molecular weight expresses 'two volumes' of the gas, the result may often be obtained directly.

Thus, what volume of hydrogen chloride is formed when 10 litres of chlorine combine with hydrogen?

$$\mathrm{Cl_2 + H_2 = 2HCl.}$$

□□ □□ 2 □□

Two volumes of chlorine form twice two volumes of hydrogen chloride, hence 10 litres of chlorine form 2 × 10 = 20 litres of hydrogen chloride.

If 10 litres of hydrogen at 15° C. are burnt, what volume of steam at 300° C. is formed?

$$\mathrm{H_2 + O = H_2O.}$$

□□ □ □□

The volume of the steam would be equal to that of the hydrogen, if the temperatures were the same; making the correction for the change of temperature

$$V = \frac{10\,(273 + 300)}{273 + 15} = \frac{5730}{288} = 19{\cdot}895 \text{ litres.}$$

When however the mass of a solid or liquid is given or asked, and the volume of a gas is asked or given, the equation can only be solved in terms of the mass of the gas.

Hence from the given volume the mass of the gas must be found by either of the last sections and the equation solved in the ordinary way.

Thus, how much lead sulphide can be precipitated by 17 litres of hydrogen sulphide?

$$\underset{34}{H_2S} + Pb2NO_3 = 2HNO_3 + \underset{239}{PbS}.$$

17 litres of hydrogen sulphide weigh $\frac{17 \times 34}{22 \cdot 4}$ grams.

34 grams of hydrogen sulphide precipitate 239 grams of lead sulphide.

1 gram of hydrogen sulphide precipitates $\frac{239}{34}$ grams of lead sulphide.

$\frac{17 \times 34}{22 \cdot 4}$ grams of hydrogen sulphide precipitate

$$\frac{17 \times 34}{22 \cdot 4} \times \frac{239}{34} = 181 \cdot 3 \text{ grams of lead sulphide.}$$

How much phosphorus can be obtained by intensely heating 10 c.c. of hydrogen phosphide?

$$\underset{2 \times 34}{2PH_3} = \underset{2 \times 31}{2P} + 3H_2.$$

10 c.c. of hydrogen phosphide weigh $\cdot 01 \times 17 \times \cdot 0896$ gms.

$$\therefore \quad \frac{\cdot 01 \times 17 \times \cdot 0896 \times 2 \times 31}{2 \times 34} = \cdot 01389 \text{ grams.}$$

Or if the volume of a gas is asked, the mass of the gas is found from the equation in the ordinary way, and its volume is then calculated by the last section.

Thus, what volume of sulphur dioxide is formed on burning 8 grams of sulphur?

$$\underset{32}{S} + O_2 = \underset{64}{SO_2}.$$

∴ 8 grams of sulphur form $\frac{8 \times 64}{32}$ grams of sulphur dioxide.

$\frac{8 \times 64}{32}$ grams of sulphur dioxide occupy

$$\frac{8 \times 64}{32} \times \frac{22 \cdot 4}{64} = 5 \cdot 6 \text{ litres.}$$

10 grams of carbon are burnt: what volume of carbon dioxide at 39° C. and 380 m.m. is formed?

$$\underset{12}{C} + O_2 = \underset{44}{CO_2}.$$

10 grams of carbon form $\frac{10 \times 44}{12}$ grams of carbon dioxide.

$\frac{10 \times 44}{12}$ grams of carbon dioxide occupy

$$\frac{10 \times 44}{12} \times \frac{22 \cdot 4}{44} \text{ litres}$$

at 0° C. and 760 m.m., which become at 39° C. and 380 m.m.

$$\frac{10 \times 44}{12} \times \frac{22 \cdot 4}{44} \times \frac{(273 + 39)}{273} \times \frac{760}{380} = 42 \cdot 6 \text{ litres.}$$

*(20) THE MASS OF A MOIST GAS.

If the volume of a gas be measured, when it is saturated with the vapour of water, the pressure measured is due partly to the gas and partly to the steam.

The tension of aqueous vapour (*F*) varies very rapidly with the temperature and must be found from tables (cf. Table IV.).

If v be the measured volume of gas and moisture in c.c. at t° C. and H m.m., d being the density of the gas and F the tension of aqueous vapour at t° C.,

the mass of the gas is $v\,\dfrac{(d \times {\cdot}0000896)}{1 + {\cdot}00367t} \times \dfrac{H - F}{760}$ grams, and the mass of the aqueous vapour contained is

$$v\,\frac{{\cdot}000806}{1 + {\cdot}00367t} \times \frac{F}{760} \text{ grams.}$$

Thus, to find the mass of nitrogen and of aqueous vapour in 200 c.c. of moist nitrogen measured at 15° C. and 730 m.m. ($F = 12{\cdot}7$),

$$M_1 = \frac{200\,(14 \times {\cdot}0000896)}{(1 + {\cdot}00367 \times 15)} \times \frac{730 - 12{\cdot}7}{760}$$

$$= {\cdot}2246 \text{ grams of nitrogen.}$$

$$M_2 = \frac{200\,({\cdot}000806)}{(1 + {\cdot}00367 \times 15)} \times \frac{12{\cdot}7}{760}$$

$$= {\cdot}00255 \text{ grams of aqueous vapour.}$$

*(21) THE DIFFUSION OF GASES.

Graham's Law. The volumes of two gases, which diffuse in equal times under the same circumstances, are inversely proportional to the square roots of their densities. Or, when two gases diffuse through the same apparatus for equal times under similar conditions, the volume of the one gas diffused multiplied by the square root of its density is equal to the volume of the other gas diffused multiplied by the square root of its density.

$$V\sqrt{D} = v\sqrt{d}.$$

4 litres of hydrogen diffuse through an apparatus in 10 minutes, and 1 litre of oxygen diffuses in an equal time under similar conditions: find the density of oxygen.

$$1\sqrt{D} = 4\sqrt{1};$$

$$\therefore \quad D = 16.$$

10 litres of oxygen ($O = 16$) diffuse through a certain apparatus in a certain time. What volume of hydrogen iodide ($HI = 128$) will diffuse in an equal time under similar conditions?

The density of oxygen is 16, and that of hydrogen iodide 64.

$$V\sqrt{64} = 10\sqrt{16},$$

$$V = 10\frac{\sqrt{16}}{\sqrt{64}} = \frac{10 \times 4}{8} = 5 \text{ litres.}$$

And how much ammonia ($NH_3 = 17$) would diffuse under similar conditions?

$$V\sqrt{8{\cdot}5} = 10\sqrt{16},$$

$$V = \frac{10 \times 4}{\sqrt{8{\cdot}5}} = 13{\cdot}7 \text{ litres.}$$

The law of effusion, or of the passage of gases through a minute hole in a thin plate, is identical with that of diffusion.

*(22) THE DETERMINATION OF VAPOUR DENSITIES.

Since the double-density of a vapour referred to hydrogen is expressed by the same number as its molecular weight, the approximate determination of vapour densities is a subject of considerable importance to Chemists.

The density of a vapour is usually determined by finding how many times a certain volume of it is heavier than an equal volume of hydrogen, under the same conditions of temperature and pressure. Numerous methods for accomplishing this have been proposed, but they may almost all be classified under two heads:—

(i) In the methods of Gay Lussac, Hofmann, Victor Meyer, and others, a known mass (M grams) of the substance is heated in an enclosed space, and the volume (V c.c.) of its vapour at T° C. under the barometric pressure H m.m., in some cases increased or decreased by a column of mercury &c. equivalent to h m.m. of mercury, is measured.

If the vapour is measured over mercury at a high temperature the tension f due to the mercury-vapour must be subtracted from the pressure on the vapour.

T°C. = 100° C.	120° C.	140° C.	160° C.	180° C.	200° C.
f = ·746 m.m.	1·534	3·06	5·9	11	19·9.

The pressure of h m.m. of mercury at T° C. is equivalent to the pressure of $\frac{h}{1+\cdot00019T}$ m.m. at the temperature of 0° C.

(At 448° C. the density of fusible alloy is about $\frac{2}{3}$ of that of mercury at 0° C.)

The vessel is usually of glass and graduated at 0° C., hence at T° C. the volume of the vessel becomes $V(1+\cdot00003T)$.

The mass of an equal volume of hydrogen under the same conditions as the vapour would be :—

$$\frac{V(1+\cdot00003T)\left(H\mp\dfrac{h}{1+\cdot00019T}\right)}{(1+\cdot00367T)\times 760}\times\cdot0000896\text{ grams.}$$

Hence the density of the vapour is found from the formula :—

$$D = \frac{M(1 + \cdot 00367T) \times 760}{V(1 + \cdot 00003T)\left(H \mp \frac{h}{1 + \cdot 00019T}\right) \times \cdot 0000896}.$$

The following numbers were obtained in the determination of the vapour-density of ethyl-propinyl ($C_5H_8O = 84$) by Hofmann's method :

$M = \cdot 0518$ grams,
$V = 52 \cdot 5$ c.c.,
$T = 100^\circ$ C.,
$H = 752 \cdot 5$ m.m.,
$h = 484$ m.m.

$$D = \frac{\cdot 0518\,(1 + \cdot 367) \times 760}{52 \cdot 5\,(1 + \cdot 003)\,(752 \cdot 5 - 475) \times \cdot 0000896}$$

$$= \frac{\cdot 0518 \times 1 \cdot 367 \times 760}{52 \cdot 5 \times 1 \cdot 003 \times 277 \cdot 5 \times \cdot 0000896} = 41 \cdot 1.$$

(ii) In the methods of Dumas, Deville and Troost, and others, a vessel, usually a glass globe holding V c.c. at 0° C., is weighed full of dry air at t_1° C. and H_1 m.m. Suppose that it weighs w grams.

A quantity of the substance is placed in the globe, which is heated to T° C., and closed when no more vapour issues from it under the pressure H_2.

It is cooled, cleaned, and found to weigh W grams.

The vessel is opened under mercury and its volume V c.c. at 0° C. determined by measurement and calculation ; if all the air has not been expelled, the volume v c.c. of the residual air at t_2° C. and H_2 mm. is determined.

If the vessel is of glass its volume V c.c. at 0° C. becomes at t_1° C. $V(1 + \cdot 00003t_1)$ and at T° C., $V(1 + \cdot 00003T)$.

The mass of the air which filled the vessel during the first weighing is

$$\frac{V(1+\cdot 00003t_1)\times H_1\times \cdot 0012932}{(1+\cdot 00367t_1)\times 760}\text{ grams.}$$

Hence the true mass of the vessel alone is

$$w-\frac{V(1+\cdot 00003t_1)\times H_1\times \cdot 0012932}{(1+\cdot 00367t_1)\times 760}\text{ grams,}$$

and the true mass of the vapour is

$$W-w+\frac{V(1+\cdot 00003t_1)\times H_1\times \cdot 0012932}{(1+\cdot 00367t_1)\times 760}\text{ grams.}$$

But the mass of a volume of hydrogen equal to and under the same conditions as the vapour at the moment of sealing the vessel is

$$\frac{V(1+\cdot 00003T)\times H_2\times \cdot 0000896}{(1+\cdot 00367T)\times 760}\text{ grams.}$$

And hence the density of the vapour is found to be

$$D=\frac{W-w+\dfrac{V(1+\cdot 00003t_1)\times H_1\times \cdot 0012932}{(1+\cdot 00367t_1)\times 760}}{\dfrac{V(1+\cdot 00003T)\times H_2\times \cdot 0000896}{(1+\cdot 00367T)\times 760}}.$$

The presence of residual air must be avoided as far as possible, since it is apt to render the results untrustworthy. The mass of the vapour found above is too great by the mass of the residual air, which must therefore be subtracted from the numerator of the fraction.

The mass of the air is $\frac{v\times H_3\times(\cdot 0012932)}{(1+\cdot 00367t_2)\times 760}$ grams.

The volume of the vapour and therefore the volume of the hydrogen has been taken too large by a volume equal to the volume, which the residual air occupied at the moment of closing the vessel. Hence the mass of this volume of hydrogen must be subtracted from the denominator of the fraction.

The mass of this volume of hydrogen is

$$\frac{v \times H_3 \times (\cdot 0000896)}{(1 + \cdot 00367 t_2) \times 760} \text{ grams.}$$

Hence the complete expression becomes

$$D = \frac{W - w + \dfrac{\cdot 0012932}{760}\left\{\dfrac{V(1 + \cdot 00003 t_1) \times H_1}{(1 + \cdot 00367 t_1)} - \dfrac{v \times H_3}{(1 + \cdot 00367 t_2)}\right\}}{\dfrac{\cdot 0000896}{760}\left\{\dfrac{V(1 + \cdot 00003 T) \times H_2}{(1 + \cdot 00367 T)} - \dfrac{v \times H_3}{(1 + \cdot 00367 t_2)}\right\}}.$$

If great accuracy is not required this formula may be considerably simplified; thus if $t_1 = t_2$ and both are small and also if $H_1 = H_2 = H_3$ the formula becomes

$$D = \frac{W - w + \cdot 000464\, H\left(\dfrac{V - v}{273 + t}\right)}{\cdot 00003216 H\left(\dfrac{V}{273 + T} - \dfrac{v}{273 + t}\right)}.$$

The following results were obtained for common alcohol ($C_2H_6O = 46$) by Dumas' method :—

Mass of globe and dry air at 13·9° C.	$w = 76{\cdot}9174$ grams.
Mass of globe & vapour sealed at 100° C.	$W = 77{\cdot}0470$ grams.
Volume of the globe	$V = 449{\cdot}32$ c. c.
Volume of residual air at 13·9° C.	$v = 3{\cdot}277$ c. c.
Height of the Barometer..................	$H = 739$ m.m.

$$D = \frac{77{\cdot}047 - 76{\cdot}9174 + \cdot 000464 \times 739 \times \left(\dfrac{446{\cdot}043}{286{\cdot}9}\right)}{\cdot 00003216 \times 739\left(\dfrac{449{\cdot}32}{373} - \dfrac{3{\cdot}277}{286{\cdot}9}\right)}$$

$= \dfrac{\cdot 661}{\cdot 027565} = 23{\cdot}97$ instead of the more nearly correct 23·4.

(23) HEAT.

Heat is one of the forms in which energy shews itself, and probably consists in the relative motion of the particles of matter.

When heat is communicated to a body, it may raise the temperature of the body, increase or rarely decrease its volume, change its physical state from solid to liquid or from liquid to gas, or cause it to undergo chemical change.

The *unit of heat* or *calorie* is the amount of heat required to raise one kilogram of water from 0 C. to 1° C.

The Specific Heat of a substance is the number of units of heat required to raise one kilogram of it from 0° C. to 1° C.

With few exceptions the specific heats are less than unity.

Dulong and Petit's Law. The specific heat of an element in the solid condition multiplied by its atomic weight is called the atomic heat of the element, and is found in the majority of cases to be nearly 6·4.

Hence, if 6·4 be divided by the specific heat of an element, a number approximately equal to its atomic weight is obtained.

Thus the specific heat of solid mercury is ·03192.

$$\frac{6{\cdot}4}{{\cdot}03192} = 200{\cdot}5. \quad Hg = 200.$$

Elements (except oxygen, carbon, hydrogen, boron, and silicon), when they have entered into combination, appear to keep the same atomic heat, which they possessed when in the free condition.

Thus Potassium Chloride KCl $6{\cdot}4 + 6{\cdot}4 = 12{\cdot}8$.

Specific heat $\cdot 17295 \times 74{\cdot}6$ (molecular weight) $= 13{\cdot}2$.

But many more experiments are needed before any accurate law can be hoped for.

The specific heat of gases under constant pressure is the one usually given in tables. The specific heat at constant volume of gases, the molecules of which consist of two atoms, may be found by dividing the specific heat under constant pressure by 1·4.

When a solid passes to the liquid or a liquid to the gaseous condition, a considerable amount of heat is absorbed and converted into a greater kinetic energy of the particles of the body. The heat so absorbed is spoken of as the latent heat of the liquid, or the gas, since it produces no change in the temperature of the body.

Heat can be converted into work and conversely work into heat. When proper precautions to avoid loss are taken, the one form of energy always produces the same equivalent quantity of the other. The amount of heat which raises one kilogram of water from 0° C. to 1° C. is able to do work equivalent to lifting 425·4 kilograms through a metre in opposition to gravity.

Hence the mechanical equivalent of the unit of heat is 425·4 kilogram-metres. This is signified by J.

Conversely the thermal equivalent of the unit of work is $\frac{1}{J} = \cdot 00235$ units of heat.

Thus to find how many kilograms could be raised through 950 metres by the heat given off by 50 kilos. of copper (sp. ht. ·095) in cooling from 200° C. to 0° C.

The heat evolved is

$$50 \times 200 \times \cdot 095 \text{ units, which can do}$$

$$50 \times 200 \times \cdot 095 \times 425\cdot 4 \text{ units of work.}$$

If x be the number of kilograms which can be raised,

$$x \times 950 = 50 \times 200 \times \cdot 095 \times 425\cdot 4,$$

$$x = 425\cdot 4 \text{ kilos.}$$

*(24) HEAT OF CHEMICAL ACTION.

When chemical action takes place heat is either evolved (exothermic reactions) or absorbed (endothermic reactions) according as the substances resulting from the reaction are more or less stable than those which have entered into it.

It is usual to express the results of the experiment by giving the amount of heat evolved or absorbed either in units of heat (kilogram-degrees) or in gram-degrees, when a number of grams of each substance is taken equal to the multiple of the atomic weight of the substance, which enters into the reaction.

Thus $(H, Cl) = 22$ means that 1 gram of hydrogen in uniting with 35·5 grams of chlorine evolves 22 units of heat.

$(H_2, O) = 69$ means that 2 grams of hydrogen in uniting with 16 grams of oxygen give off 69 units of heat.

If the reaction takes place in presence of excess of water, or if a substance is dissolved in excess of water, the indeterminate quantity of water is expressed by Aq.

Thus $(NH_3, Aq) = 8$ means that 17 grams of ammonia, while dissolving in water, give off 8 units of heat.

When during a reaction heat is not evolved but absorbed, its amount is preceded by a minus sign.

Thus $(C_2, H_4) = -10{\cdot}8$ means that during the formation of ethene from 24 grams of carbon and 4 grams of hydrogen 10·8 units of heat are absorbed.

In the important class of cases in which substances burn or combine with oxygen the following special terms are used.

The *calorific power* of a substance is measured by the number of units of heat evolved when 1 kilogram of it is burnt in oxygen.

The *calorific intensity* of a substance is measured by the temperature to which it can raise the products of its own combustion.

If a kilogram of a substance in burning evolves Q units of heat, and forms products the masses of which are m_1, m_2, m_3, &c., and their specific heats s_1, s_2, s_3, &c., the calorific intensity $I = \frac{Q}{m_1s_1 + m_2s_2 + m_3s_3 + \&c.}$.

Thus to find the calorific intensity of carbon, the calorific power of which is 8080, the specific heat of carbon dioxide being ·202.

$$C + O_2 = CO_2.$$

12 kilos. of carbon form 44 kilos. of carbon dioxide,

1 kilo. „ forms $\frac{44}{12}$ „ „ „

Hence $I = \frac{8080 \times 12}{\cdot 202 \times 44} = 10909°$ C.

From the calorific intensity the pressure exerted by a mixture of gases exploded in a closed space may be calculated by finding first the temperature to which the mixture is raised by its own combustion, next the volume which the products of combustion would occupy at that temperature, and lastly the pressure required to compress the products of combustion within the volume of the enclosing vessel.

Thus to find the explosive force of a mixture of carbon monoxide and oxygen:—

A kilogram of carbon monoxide in burning evolves 2400 units of heat and forms $\frac{44}{28}$ kilos. of carbon dioxide having the specific heat at constant volume 0·17.

Hence $I = \frac{2400 \times 28}{0{\cdot}17 \times 44} = 9000°$ C. nearly.

In combining two volumes of carbon monoxide and one volume of oxygen contract to form two volumes of carbon dioxide; hence 1 volume of the mixed gases forms only $\frac{2}{3}$ volume of carbon dioxide. But this $\frac{2}{3}$ volume when heated to 9000° C. becomes

$$\tfrac{2}{3}\left\{1+\frac{11\times 9000}{3000}\right\}=\frac{2\times 34}{3}=22{\cdot}6 \text{ volumes.}$$

And to reduce these 22·6 volumes to one volume requires a pressure of 22·6 atmospheres, which therefore is the explosive force of the gaseous mixture.

It must be noticed, that, as the specific heat at constant volume differs from that under constant pressure, each gas has two calorific intensities according as it is burnt in a closed or open space.

There are so many assumptions, unwarranted as yet by experiment, in the majority of these calculations, that it is doubtful if the results are more than rough approximations to the truth.

(25) THE DETERMINATION OF EQUIVALENTS.

The equivalent of an element or compound is the proportion of it, which can do the same amount of chemical work in combining with or replacing other elements or compounds, as one part of hydrogen.

The equivalent of an element is determined either by analysing a compound of it with an element or radical the equivalent of which is known, or by causing a known mass of it to combine with or replace another element or radical the equivalent of which is known.

The masses of the two substances which unite with or replace one another are in the same proportion as the equivalents or as multiples of the equivalents by small whole numbers. Hence knowing the two masses and one of the equivalents the other equivalent may be determined.

Thus to determine the equivalent of lead, that of oxygen being 8, Berzelius found that 21·9425 grams of lead oxide contain 20·3695 grams of lead, and hence $21{\cdot}9425 - 20{\cdot}3695 = 1{\cdot}573$ grams of oxygen.

Since 1·573 grams of oxygen unite with 20·3695 grams of lead, 8 grams of oxygen unite with $\frac{8 \times 20{\cdot}3695}{1{\cdot}573} = 103{\cdot}596$ grams of lead. Hence 103·596 is the equivalent of lead.

Again when excess of cupric oxide was heated in hydrogen, the oxide lost 59·789 grams and 67·282 grams of water were formed.

$$cu\,o + h = h\,o + cu.$$

Since 67·282 grams of water contain 59·789 grams of oxygen, the residue or 7·493 grams is hydrogen.

Therefore 7·493 grams of hydrogen unite with 59·789 grams of oxygen, or 1 gram of hydrogen unites with $\frac{59{\cdot}789}{7{\cdot}493}$ grams of oxygen. Hence 7·979 is the equivalent of oxygen.

(26) THE DETERMINATION OF ATOMIC WEIGHTS.

The atomic weight of an element is the mass of the least portion of it, which can take part in a chemical change, compared with the mass of the least portion of hydrogen which can take part in a chemical change. If the atomic theory be admitted, the atomic weight of an element is the number of times its atom is heavier than an atom of hydrogen.

Atomic weights are in all cases multiples of the equivalents of the elements by small (1—8) whole numbers. Which multiple is to be chosen is determined by a careful consideration of all the reactions into which the element is known to enter, with the object of detecting the smallest multiple of the equivalent which may be considered to take part in each case; special attention being paid to compounds with monovalent elements or groups.

Further assistance is rendered by the isometric law of Mitscherlich; that, "Bodies, which are composed of the same number of similar atoms arranged in the same manner, crystallize in similar forms." And also by the law of Dulong and Petit; that, "6·4 divided by the specific heat of an element in the solid condition gives a number which is approximately equal to the number expressing the atomic weight of the element."

There are however somewhat numerous exceptions to both these laws.

Thus to find the atomic weight of lead, the equivalent of which has been found to be 103·596.

The choice has to be made between the various multiples by 1, 2, 3, 4, &c. or 103·596, 207·192, 310·798, 414·384, &c.

The specific heat of lead is found to be ·0315, and

$$\frac{6{\cdot}4}{{\cdot}0315} = 203{\cdot}1.$$

Hence 207·192 is the most probable atomic weight of lead.

(27) THE DETERMINATION OF MOLECULAR WEIGHTS.

In considering the methods of finding the symbols of bodies, which represent their molecular weights, it is convenient to consider first the case of compounds and then that of elements.

The molecular weight of a body is the number of times which the mass of the smallest portion of it, which can exist by itself or in the free state, is heavier than the atom of hydrogen.

When a compound is analysed, the results are usually calculated into percentages or parts of each element present in 100 parts of the compound. If then the proportion of each element present be divided by the atomic weight of that element, the quotients express the relative number of atoms of each element present in the compound.

Thus hydrogen phosphide is found to contain:—

Phosphorus 91·18, $\frac{91\cdot18}{31} = 2\cdot94$ times P present.

Hydrogen $\begin{array}{r}\underline{8\cdot82}\\ 100\cdot00\end{array}$, $\frac{8\cdot82}{1} = 8\cdot82$ times H present.

[When water is present as water of crystallization, it is usual not to calculate the number of atoms of hydrogen and oxygen separately, but to reckon it as though it were an element, $H_2O = Aq = 18$.]

To accord with the atomic theory the proportions expressed by these quotients must be expressible by whole numbers usually small. If simple inspection affords no clue there are three methods of effecting this reduction:—

(i) Divide each quotient by the smallest quotient, all then frequently become whole numbers or may be made so by multiplication in each case by the same number.

Thus in the case taken above:—

$$\frac{2{\cdot}94}{2{\cdot}94} = 1\text{P}, \frac{8{\cdot}82}{2{\cdot}94} = 3\text{H}, \text{ and the formula is } PH_3.$$

(ii) Write instead of one quotient an easily divisible number, such as 6, 12, 28, 60, 210, 360, and alter the other quotients in the same proportion. Division by the greatest common measure then frequently gives the small whole numbers required.

Thus crystallized ferrous sulphate is found to contain:—

Iron 20·15, $\frac{20{\cdot}15}{56} \times \frac{12 \times 16}{23{\cdot}02} = 3 \div 3 = 1.$

Sulphur 11·51, $\frac{11{\cdot}51}{32} \times \frac{12 \times 16}{23{\cdot}02} = 3 \div 3 = 1.$

Oxygen 23·02, $\frac{23{\cdot}02}{16}$, replace by $12 = 12 \div 3 = 4.$

Water 44·31, $\frac{44{\cdot}31}{18} \times \frac{12 \times 16}{23{\cdot}02} = 21 \div 3 = 7.$

Hence the formula is $FeSO_4 . 7H_2O$.

*(iii) It occasionally happens, usually in the case of organic compounds, that the ratio between the quotients is too complicated to be conveniently reduced by either of the foregoing methods. The continued fraction (Sect. 6) expressing the ratio between two of the quotients must then be

found, and that convergent selected, which expresses the ratio in the lowest terms within the limits of experimental error.

Thus common sugar is found to contain:—

Carbon 42·11, and $\frac{42{\cdot}11}{12} = 3{\cdot}51$ atoms of carbon.

Hydrogen 6·43, and $\frac{6{\cdot}43}{1} = 6{\cdot}43$ atoms of hydrogen.

Oxygen 51·46, and $\frac{51{\cdot}46}{16} = 3{\cdot}215$ atoms of oxygen.

In this case the number of atoms of hydrogen is double of the number of atoms of oxygen, and only the ratio of the number of atoms of carbon to the number of atoms of oxygen has to be reduced.

$\frac{3{\cdot}51}{3{\cdot}215} = \frac{702}{643}$ being worked out as a continued fraction gives,

```
643)702(1
    643
    ---
     59)643(10
        590
        ---
         53)59(1
            53
            --
             6)53(8
               48
               --
                5)6(1
                  5
                  -
                  1
```

Hence the quotients are 1, 10, 1, 8, 1,

and the convergents $\frac{1}{1}, \frac{11}{10}, \frac{12}{11}, \frac{107}{98}$.

Hence the ratio between the carbon and oxygen atoms is probably expressed by $\frac{12}{11}$, and the formula of cane-sugar is $C_{12}H_{22}O_{11}$.

The next step is to determine which multiple of the symbol obtained by either of the methods mentioned above is to be taken as representing the true molecular weight of the body.

There are two general methods of effecting this, but in many cases neither is applicable.

(i) The Physical Method:—The vapour density of the body is determined by one of the methods mentioned in (Sect. 22), and it is assumed that the double-density of the body is expressed by nearly the same number as the molecular weight.

The cases mentioned in (Sect. 17) are assumed to be exceptions to the law, and a few others are known to exist. The use of this method of course pre-supposes that the substance can be obtained in the state of vapour without decomposition.

Thus cuprous chloride is composed of 63·3 parts of copper combined with 35·5 parts of chlorine, and its molecular weight is expressed by $CuCl = 98{\cdot}8$ or by some multiple of this number.

But the vapour of cuprous chloride is found to be 6·93 times as heavy as air, or its double-density is 200·08, and hence its symbol is $Cu_2Cl_2 = 197{\cdot}6$.

(ii) The Chemical Method:—Some compounds or substitution products of the substance are analysed, e.g. if it be an acid its silver salt; if it be a base its nitrate, chloride, or bromide; if it be an organic body its chloro- or bromo-substitution compounds.

And that formula is chosen for the body, which most readily expresses the mode of formation and constitution of these compounds.

Thus to determine the molecular weight of hydrogen acetate, which is found to contain:—

Carbon	40	$\frac{40}{12} = 3{\cdot}3$	1.
Hydrogen	6·6	$= 6{\cdot}6$	2.
Oxygen	53·4	$\frac{53{\cdot}4}{16} = 3{\cdot}3$	1.
	100·0		

Hence the formula is CH_2O, or some multiple of this symbol.

When sodium acetate is mixed with silver nitrate, silver acetate is formed, which is found to contain:—

Carbon	14·37	$\frac{14{\cdot}37}{12} = 1{\cdot}2$	nearly	2.
Hydrogen	1·79	$= 1{\cdot}8$	„	3.
Silver	64·68	$\frac{64{\cdot}68}{108} = {\cdot}6$	„	1.
Oxygen	19·16	$\frac{19{\cdot}16}{18} = 1{\cdot}2$	„	2.
	100·00			

Hence the most simple formula which expresses the composition of silver acetate is $C_2H_3AgO_2$.

Again, by acting on hydrogen acetate with chlorine in sunlight, hydrogen trichloracetate is formed, which is found to contain:—

Carbon	14·68	$\frac{14\cdot68}{12}=1\cdot22$	2.
Hydrogen	·61	$=\cdot61$	1.
Chlorine	65·14	$\frac{65\cdot14}{35\cdot5}=1\cdot83$	3.
Oxygen	19·57	$\frac{19\cdot57}{16}=1\cdot22$	2.
	100·00		

The most simple formula for hydrogen trichloracetate is therefore $C_2HCl_3O_2$.

Hence it is most probable that the original hydrogen acetate contains at least two atoms of carbon, four atoms of hydrogen, and two atoms of oxygen, or that its symbol is $C_2H_4O_2$.

The above reactions are then simply expressed as follows:—

$$NaC_2H_3O_2 + AgNO_3 = NaNO_3 + AgC_2H_3O_2.$$
$$C_2H_4O_2 + 3Cl_2 = 3HCl + C_2HCl_3O_2.$$

Since with four exceptions the vapour densities of such of the elements as have been examined in the gaseous condition are found to be expressed by the same numbers as their atomic weights; it seems most probable that their molecular weights also are expressed by numbers equal to those expressing their double-densities or by twice their atomic weights.

The elements for which the above has been shewn to be true are hydrogen, oxygen, nitrogen, chlorine, bromine, iodine, sulphur (above 1000° C.), selenium, tellurium and potassium.

In the cases of mercury and cadmium, the density of their vapours is found to be only half their atomic weights, or the double-density and probably the molecular weight is equal to the atomic weight.

In the cases of phosphorus and arsenic, the density of their vapours is found to be twice their atomic weights; or the double-density and probably the molecular weight is equal to four times the atomic weight.

The conclusion, that in the case of the ten elements mentioned above the molecular is double of the atomic weight, is borne out by four other kinds of proof.

(i) When chlorine and hydrogen unite, the particles of chlorine and of hydrogen split up into twice the number of smaller particles.

(ii) Phosphorus and carbon when burnt in nitrous oxide evolve more heat than when burnt in oxygen.

(iii) Elements when just set free, in the nascent condition, are much more active than in their ordinary state.

(iv) Reduction of oxidized bodies by oxides and of hydrogenized bodies by hydrides is most easily explained by assuming an attraction of oxygen for oxygen and of hydrogen for hydrogen, the two similar atoms subsequently uniting to form one molecule.

*(28) THE FORMULÆ OF MINERALS.

In determining the formulæ of minerals numerous difficulties are met with which do not occur in ordinary determinations of molecular weights.

No help can be obtained from vapour density determinations, and only in rare cases can any compounds of the mineral be formed. The body analysed is frequently far from pure and hence the results are only approximate, and the percentages obtained do not represent the true composition of the mineral. The composition in many cases, especially when silica, alumina and water are present together, is extremely complicated, part of the alumina performing basic and part acid functions.

Frequently also a metal is replaced by a similar metal not in atomic proportions, thus ferrous iron may replace calcium and ferric iron aluminium in any proportion; this is expressed in formulæ by $[FeCa]$ $[Fe_2Al_2]$.

Silicates are classified by mineralogists according to their "oxygen-ratio," that is by the ratio between the number of atoms of oxygen supposed to be in combination with the metals, and the number of atoms of oxygen supposed to be in combination with silicon.

Thus calcium metasilicate $CaSiO_3$ is found native as Wollastonite, and its formula is written $CaO . SiO_2$, the oxygen-ratio being 1 : 2. In Diopside more or less of the calcium is replaced, by magnesium and the formula is written

$$[CaMg] O. SiO_2.$$

Recently however it has been proposed to bring mineralogical formulæ more into accordance with modern chemical theories, by discarding the term 'oxygen-ratio' and replacing it by 'Quantivalent ratio,' which is intended to mean the ratio of the metallic bodies present to the non-metallic bodies present in respect of valency.

Thus Wollastonite would now be regarded as a dyad metal, calcium, united by two atoms of oxygen to an atom of tetrad silicon, two atomicities of which are also satisfied by oxygen. This is expressed by the formula $Ca''O_2Si^{IV}O$. And members of the garnet family are expressed by

$$([Ca]O)_3 ([Al_2]O_3) (SiO_2)_3 \text{ or } [Ca'']_3 [Al_2{}^{VI}] O_{12} Si_3{}^{IV}.$$

From the use of the oxygen-ratio it became customary to calculate the results of analysis not into percentages of elements, but into percentages of oxides, and in all subsequent calculations to treat the oxides just as if they were elements ($SiO_2 = 60$. $Al_2O_3 = 102$. $CaO = 56$ &c.). The formulæ then were obtained by processes similar to those given in the last section.

Thus to find the formula of chrysocolla which contains:—

Cupric oxide	44·82	$\frac{44·82}{79·3} =$	·565	1.
Silica	34·83	$\frac{34·83}{60} =$	·58	1.
Water	20·35	$\frac{20·35}{18} =$	1·13	2.
	100·00			

Hence the formula of chrysocolla is $CuO. SiO_2. 2H_2O$.

If one or more similar oxides are present in small proportion, they have probably replaced one another, and must all be reduced to terms of one of them, by adding the numbers representing the ratio of their molecules present, before the calculation can be proceeded with.

Thus a brown deposit of sinter was found to contain

Silica	18·98	$\frac{18·98}{60} =$	·316	·316	1.
Manganic oxide	25·11	$\frac{25·11}{158} =$	·16	·303	1.
Ferric oxide	22·9	$\frac{22·9}{160} =$	·143		
Water	33	$\frac{33}{18} =$	1·83	1·83	6.

Hence the formula of the sinter is

$$[Fe_2Mn_2]O_3 . SiO_2 . 6H_2O.$$

In the case of silicates containing alumina it is often impossible to determine except from theory what proportion of the alumina is basic and what proportion is acid in its functions.

A sample of Andalusite was found to contain:—

Silica	37·57	$\frac{37·57}{60}$ = ·626	·626.
Alumina	59·88	$\frac{59·88}{102}$ = ·587	·595.
Ferric oxide	1·33	$\frac{1·33}{160}$ = ·008	
Lime	0·61	$\frac{·61}{56}$ = ·011	·015.
Magnesia	0·17	$\frac{·17}{40}$ = ·004	

Hence, neglecting the small proportions of Lime and Magnesia, which are probably present as silicates and hence raise the ratio of the silica, the formula of the mineral is

$$Al_2O_3 . SiO_2.$$

In Andalusite a portion of the alumina is probably basic and a portion acid, the rational formula being:—

$$(Al_2)^{vi}\begin{cases}(SiO_3)_2''\\(AlO_2)_2'\end{cases}.$$

*(29) THE SOLUBILITY OF SOLIDS.

Though many experiments on the solubility of solids in liquids have been made, no general law connecting chemical composition and solubility has yet been discovered. Water is by far the most general solvent, and with it alone sufficient experiments have been made to justify any attempt at a general law.

When solids dissolve in water heat is generally absorbed by the solid in passing to the liquid condition. But if the substance previously combines with water to form a hydrate which subsequently dissolves, the heat evolved in the formation of the hydrate may supply or more than supply the quantity required for the solution of the solid.

The volume of the solution is generally less than the volumes of the solid and liquid together, and its boiling-point is usually above 100° C.

The solubility of a solid is usually measured at any temperature t° C., by the number of grams (x) of the solid which 100 grams of water will dissolve.

If the mass of any saturated solution be M grams, and m grams of the salt are dissolved in it

$$M - m : m :: 100 : x;$$

$$\therefore\ x = \frac{100\,m}{M - m}.$$

And if y be the number of grams of water required to dissolve 1 gram of the substance,

$$x : 100 :: 1 : y,$$

$$x = \frac{100}{y}.$$

If 100 grams of the solution contain n grams of the salt,

$$100 - n : n :: 100 : x,$$

$$x = \frac{100n}{100 - n}.$$

Generally speaking the solubility of the substance increases with and more rapidly than the temperature of the water, so that,

$$x = a + bt + ct^2 + dt^3,$$

where a, b, c and d are constants depending upon the nature of the substance under consideration.

In the great majority of cases b, c, and d have not been accurately determined; in a few cases e.g. calcium hydrate and strontium sulphate the solubility decreases as the temperature rises or b, c, and d are affected with minus signs.

In a few other cases, e.g. sodium and calcium sulphates, the solubility increases up to a certain temperature and then decreases. This is due to the formation of different hydrates at different temperatures, each hydrate following its own law of solubility.

Thus below about 18° C. the sodium sulphate is in the condition of the sept-hydrated salt $Na_2SO_4 . 7H_2O$, between 18° C. and 33° C. in that of the ordinary Glauber's salts $Na_2SO_4 . 10H_2O$, while at temperatures above 34° C. the salt is in the anhydrous condition as Na_2SO_4.

Gay Lussac found for the solubility of potassium nitrate

$$x = 13{\cdot}82 + 0{\cdot}574t + 0{\cdot}0172t^2 + 0{\cdot}0000036t^3.$$

How much potassium nitrate will dissolve in a kilogram of water at 100° C.?

$x = 13{\cdot}82 + 57{\cdot}4 + 172 + 3{\cdot}6 = 246{\cdot}82$ grams in 100 grams of water, hence a kilogram of water will dissolve

$$246{\cdot}82 \times 10 = 2468{\cdot}2 \text{ grams of the salt.}$$

And in how many parts of water at 100° C. is one part of potassium nitrate soluble?

$$246{\cdot}82 : 100 :: 1 : y,$$

$$\therefore y = {\cdot}40516 \text{ part of water.}$$

Liquids may be quite insoluble in one another, and when shaken together separate into two distinct layers e.g. water and mercury; or they may mix together in all proportions e.g. water and alcohol; or they may separate into two layers, the lower one consisting chiefly of one liquid mixed with a definite proportion of the other, and the upper one consisting chiefly of the second liquid mixed with a definite proportion of the first liquid e.g. water and ether.

No general numerical rules concerning the solubility of liquids have yet been obtained.

*(30) THE SOLUBILITY OF GASES IN LIQUIDS.

Gases are absorbed by water, when they do not act chemically upon it, in quantities depending upon three conditions:

1st. The nature of the gas. The volume of each normal gas absorbed by one volume of water at 0° C. is called the absorption coefficient of that gas.

2nd. The pressure on the gas. The quantity of a gas absorbed varies directly as the pressure upon it: or, equal volumes of the same gas are absorbed at all pressures.

3rd. The temperature. With few exceptions the volume of gas absorbed decreases as the temperature increases.

The volume of a gas absorbed at any temperature t° C. can be expressed by the empirical formula

$$V = a - bt + ct^2.$$

Thus one volume of water between 0° C. and 20° C. absorbs of

Hydrogen	$V = 0{\cdot}0193.$
Nitrogen	$V = 0{\cdot}020346 - 0{\cdot}00053887t + 0{\cdot}000011156t^2.$
Oxygen	$V = 0{\cdot}04114 - 0{\cdot}00109t + 0{\cdot}0000226t^2.$
Carbon dioxide	$V = 1{\cdot}7967 - 0{\cdot}07761t + 0{\cdot}0016424t^2.$
Oxygen and nitrogen from air	$V = 0{\cdot}02471 - 0{\cdot}0006525t + 0{\cdot}00001345t^2.$

If two or more gases are mixed together, the absorption of each constituent is proportional to the pressure to which it is separately subjected.

Thus suppose a large excess of air be shaken up with water at 0° C. in what proportions per cent. are the oxygen and nitrogen absorbed?

100 volumes of air contain nearly 21 volumes of oxygen, and 79 volumes of nitrogen.

Hence the pressure on the oxygen is $\frac{21}{100}$ of the total pressure, and the pressure on the nitrogen is $\frac{79}{100}$ of the pressure.

The volume of oxygen absorbed by 1 volume of water is $\frac{{\cdot}04114 \times 21}{100}$ volume, and the volume of nitrogen absorbed by 1 volume of water is $\frac{{\cdot}020346 \times 79}{100}$ volume.

Hence 2·471274 volumes of gas are absorbed by 100 volumes of water, of which 0·86394 volume is oxygen and 1·60733 volumes are nitrogen.

And the percentage composition of the gas absorbed by water is

Oxygen	34·9	per cent. by volume.
Nitrogen	65·1	” ” ”

*LOGARITHMIC ARITHMETIC.

(31) TO FIND THE LOGARITHM OF A NUMBER FROM TABLES.

The common logarithm of a number is the power to which 10 must be raised to be equal to the number.

If $10^x = N$. x is the logarithm of N.

A logarithm may be either a whole number, a decimal or a mixed number. The part of a logarithm which is a whole number is called the characteristic, and the part which is decimal is called the mantissa.

$$\begin{aligned} \text{Since} \qquad 1 &= 10^0, & \log 1 &= 0, \\ 10 &= 10^1, & \log 10 &= 1, \\ 100 &= 10^2, & \log 100 &= 2, \\ 1000 &= 10^3, & \log 1000 &= 3. \end{aligned}$$

Hence the characteristic for a number greater than unity is one less than the number of figures in the integral part of the number.

When a characteristic is negative the minus sign is written over and not before the characteristic, to shew that

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Hence the characteristic for a number greater than unity is one less than the number of figures in the integral part of the number.

When a characteristic is negative the minus sign is written over and not before the characteristic, to shew that

it affects only the characteristic and not the mantissa, which always remains positive.

$$\text{Since}\quad \cdot 1 = \frac{1}{10} = 10^{-1}, \qquad \log \cdot 1 = \bar{1}.$$

$$\cdot 01 = \frac{1}{100} = 10^{-2}, \qquad \log \cdot 01 = \bar{2}.$$

$$\cdot 001 = \frac{1}{1000} = 10^{-3}, \qquad \log \cdot 001 = \bar{3}.$$

The characteristic of a decimal is negative and is one more than the number of ciphers following the decimal point. Or the characteristic of a decimal is represented by the same figure as the place of the first significant figure reckoned from the decimal point.

The characteristic is not given in the tables and must be determined by the above rules.

The mantissa, or decimal part of the logarithm, is found in the tables, and is always the same for the same figures wherever the decimal point may come.

$$\begin{aligned} \text{Thus}\quad \log 2 &= \cdot 3010, & \log \cdot 2 &= \bar{1}\cdot 3010,\\ \log 20 &= 1\cdot 3010, & \log \cdot 02 &= \bar{2}\cdot 3010,\\ \log 200 &= 2\cdot 3010, & \log \cdot 002 &= \bar{3}\cdot 3010,\\ \log 2000 &= 3\cdot 3010, & \log \cdot 0002 &= \bar{4}\cdot 3010. \end{aligned}$$

Logarithm tables of different sizes may be obtained giving the mantissæ to 7, 6, or 5 decimal places. Generally speaking the results obtained are correct to one figure less than the number of figures in the mantissæ of the logarithms used, the succeeding figure being only approximate.

For chemical purposes tables giving the mantissæ to four figures are usually sufficient, such tables give results correct to the third figure and nearly so to the fourth figure*.

To find in such a table the logarithm of a number consisting of three figures, look for the first two figures in the vertical column of numbers, and for the third figure look at the top of the page. Cf. Table XII.

The required mantissa will be found where the row and column meet. Prefix the characteristic.

Thus $\log 64 = 1{\cdot}8062, \quad \log 647 = 2{\cdot}8109.$

If the number consist of four figures, find the mantissa corresponding to the first three figures as given above, look along the same row into the subsidiary table on the right hand side of the page until the column under the fourth figure is reached, and add in the small logarithm found there.

Thus
$$\log 6473 = 3{\cdot}8109 + 2 = 3{\cdot}8111,$$
$$\log 6599 = 3{\cdot}8189 + 6 = 3{\cdot}8195.$$

The reason for adding in these small logarithms to represent the fourth figure is as follows:—

The logarithm of 6470 is 3·8109,
and the logarithm of 6480 is 3·8116.

Hence a difference of 10 in the last two figures of the number produces a difference of 7 in the last figure of the logarithm, or a difference of 1 in the fourth figure of the number produces a difference of ·7 in the fourth figure of the logarithm.

---

* Logarithm cards to 4 figures price 6*d*. may be obtained from Mr J. C. Wilbee, bookseller, Harrow.

Hence a difference in the fourth figure of	1	2	3	4	5	6	7	8	9
produces a difference in the logarithm of	·7	1·4	2·1	2·8	3·5	4·2	4·9	5·6	6·3
or taking the nearest whole numbers of	1	1	2	3	3	4	5	6	6

Hence these small additions to the logarithms are spoken of as differences, they are nearly though not exactly proportional to the differences between the numbers.

(32) TO FIND A NUMBER FROM ITS LOGARITHM.

Neglecting the characteristic, find in the tables the mantissa next below that of the given logarithm, take for the first two figures of the number those at the left hand of the row in which the mantissa stands, and for the third figure of the number that at the top of the column in which the mantissa stands.

To find the fourth figure of the number subtract the mantissa found in the tables from that of the given logarithm, and look along the row for the next smaller difference; the figure standing at the top of that column of differences is the required fourth figure of the number.

Reckon the position of the decimal point from the characteristic.

Thus *$\log^{-1} \cdot 8062 = 6 \cdot 4$, $\log^{-1} 1 \cdot 8149 = 65 \cdot 3$,

$\log^{-1} \bar{4} \cdot 7782 = \cdot 0006$, $\log^{-1} \cdot 0012 = 1 \cdot 003$.

$\log^{-1} 2 \cdot 8095 = 644 \cdot 9$, $\log^{-1} \bar{3} \cdot 7821 = \cdot 006054$

$$\begin{array}{r} 89 \\ \hline 6 \end{array} \text{ diff. for 9.} \qquad \begin{array}{r} 18 \\ \hline 3 \end{array} \text{ diff. for 4.}$$

It must be remembered that the fourth figure obtained by four-figure logarithms may be too great or too small by 1.

---

* $\log^{-1}$ means find the number from its logarithm.

(33) THE USE OF LOGARITHMS.

The four following rules give the chief uses of logarithms.

(i) To multiply numbers add their logarithms, and the sum is the logarithm of the product.

Thus 47×63.

$$\begin{array}{lr} \log 47 = & 1\cdot6721 \\ \log 63 = & 1\cdot7993 \\ \cline{2-2} \log^{-1} & 3\cdot4714 = 2961. \end{array}$$

Again $47\cdot81 \times 64 \times \cdot027$.

$$\begin{array}{lr} \log 47\cdot81 = & 1\cdot6795 \\ \log 64 = & 1\cdot8062 \\ \log \cdot027 = & \bar{2}\cdot4314 \\ \cline{2-2} \log^{-1} & 1\cdot9171 = 82\cdot61. \end{array}$$

(ii) To divide numbers subtract the sum of the logarithms of the divisors from the sum of the logarithms of the dividends, the difference is the logarithm of the quotient.

Thus $\frac{48}{24}$.

$$\begin{array}{lr} \log 48 = & 1\cdot6812 \\ \log 24 = & 1\cdot3802 \\ \cline{2-2} \log^{-1} & \cdot3010 = 2. \end{array}$$

Again $\frac{\cdot763}{494}$.

$$\begin{array}{lr} \log \cdot763 = & \bar{1}\cdot8825 \\ \log 494 = & 2\cdot6937 \\ \cline{2-2} \log^{-1} & \bar{3}\cdot1888 = \cdot001545. \end{array}$$

Lastly $\frac{476 \times 760 \times \cdot074}{37 \times 43}$.

$$\begin{array}{lr} \log 37 = & 1\cdot5682 \\ \log 43 = & 1\cdot6335 \\ \cline{2-2} & 3\cdot2017 \end{array}$$

$$\begin{array}{lr} \log 476 = & 2\cdot6776 \\ \log 760 = & 2\cdot8808 \\ \log \cdot074 = & \bar{2}\cdot8692 \\ \cline{2-2} & 4\cdot4276 \end{array}$$

$$\begin{array}{lr} & 4\cdot4276 \\ & 3\cdot2017 \\ \cline{2-2} \log^{-1} & 1\cdot2259 = 16\cdot82. \end{array}$$

(iii) To find the power of a number multiply the logarithm of the number by the index of the power to which it is to be raised, and the product is the logarithm of the required power.

$$\text{Thus } 2^{10}. \qquad \begin{array}{r} \log 2 = \cdot 30103 \\ 10 \\ \hline \log^{-1} 3\cdot 0103 = 1024. \end{array}$$

$$\text{Again } (9\cdot 163)^4. \qquad \begin{array}{r} \log 9\cdot 163 = \cdot 9620 \\ 4 \\ \hline \log^{-1} \quad 3\cdot 8480 = 7047. \end{array}$$

$$\text{Lastly } (\cdot 0037)^3 \qquad \begin{array}{r} \log \cdot 0037 = \bar{3}\cdot 5682 \\ 3 \\ \hline \log^{-1} \bar{8}\cdot 7046 = \cdot 0000000506. \end{array}$$

(iv) To find the root of a number, divide the logarithm of the given number by the index of the root which is to be extracted, the quotient is the logarithm of the required root.

$$\text{Thus } \sqrt[3]{12340} \qquad \log 12340 = 4\cdot 0913,$$

$$\log^{-1} \frac{4\cdot 0913}{3} = \log^{-1} 1\cdot 3628 = 23\cdot 06.$$

If the root of a decimal, the logarithm of which has a negative characteristic, has to be found, a number must be added both to the characteristic and mantissa such as to make the characteristic an exact multiple of the index of the root by which it is to be divided. The root is then found by the method given above.

Thus $\sqrt[4]{\cdot 007654}$ $\quad \log \cdot 007654 = \bar{3}\cdot 8839$; add 1 to each.

$$\frac{\bar{4} + 1\cdot 8839}{4} = \bar{1}\cdot 4709. \quad \log^{-1} \bar{1}\cdot 4709 = \cdot 29575.$$

Again $\sqrt{\frac{2}{3}}$. $\quad \log 2 - \log 3 = \bar{1}\cdot 8239$; add 1 to each.

$$\frac{\bar{2} + 1\cdot 8239}{2} = \bar{1}\cdot 9119. \quad \log^{-1} \bar{1}\cdot 9119 = \cdot 8164.$$

(34) EXAMPLES OF THE USE OF LOGARITHMS IN SOLVING CHEMICAL PROBLEMS.

It is evident that in complicated cases, after all signs of addition and subtraction have been got rid of, the results are more easily obtained by logarithmic than by common arithmetic.

It is worth while to remember the logarithms of a few numbers which constantly occur, such as

$$\log 3\cdot 14159 = \cdot 4971, \quad \log 22\cdot 32 = 1\cdot 3487,$$
$$\log 760 = 2\cdot 8808, \quad \log \cdot 0896 = \bar{2}\cdot 9523.$$

A few examples of different kinds of problems will now be given:

(i) The expansion of gases by heat.

It was pointed out at the end of Section 16, that the expansion of a gas may be represented by the formula

$$V = \frac{v(1 + \cdot 00367T)}{1 + \cdot 00367t},$$

where ·00367 is the coefficient of expansion of the gas which is usually expressed by α.

If a table of the logarithms of $(1 + \cdot 00367t)$ has been prepared for the different values of t, it is easy to calculate the change in volume produced by any change in temperature. Cf. Table VII.

Thus, to find the new volume if 1000 c.c. of gas are heated from 0° C. to 47° C.

$$V = \frac{1000\,(1 + \cdot 00367 \times 47)}{1},$$

$$\begin{array}{rr} \log 1000 = & 3\cdot 0000 \\ \log(1 + a\,47) = & \cdot 0691 \\ \hline \log^{-1} & 3\cdot 0691 = 1172 \text{ c. c.} \end{array}$$

If differences are given in these tables they are usually given for 1° C.

Again 1426 c. c. of gas are heated from 40° C. to 50° C., find the new volume.

$$V = \frac{1426\,(1 + a\,50)}{1 + a\,40};$$

$$\begin{array}{rr} \log 1426 = & 3\cdot 1541 \\ \log(1 + a\,50) = & \cdot 0731 \\ \hline & 3\cdot 2272 \\ \log(1 + a\,40) & \cdot 0595 \\ \hline \log^{-1} & 3\cdot 1677 = 1471 \text{ c.c.} \end{array}$$

(ii) The diffusion of gases is treated with great facility by logarithms.

If 436 c. c. of hydrogen chloride ($HCl = 36\cdot 5$) diffuse through a certain apparatus in a certain time, what volume of hydrogen bromide ($HBr = 81$) will diffuse under the same conditions?

$$V \times \sqrt{\frac{81}{2}} = 436 \times \sqrt{\frac{36{\cdot}5}{2}},$$

$$V = \frac{436\sqrt{18{\cdot}25}}{\sqrt{40{\cdot}5}};$$

$$\begin{array}{rl}
\log 436 = & 2{\cdot}6395 \\
\log \sqrt{18{\cdot}25} = & \underline{{\cdot}6306} \\
 & 3{\cdot}2701 \\
\log \sqrt{40{\cdot}5} & \underline{{\cdot}8038} \\
\log^{-1} & 2{\cdot}4663 = 292{\cdot}6 \text{ c.c.}
\end{array}$$

(iii) Calculate the percentage composition of theine. $C_8H_{10}N_4O_2$.

$$\begin{array}{rrr}
8\,C = & 96 & 49{\cdot}5 \\
10\,H = & 10 & 5{\cdot}15 \\
4\,N = & 56 & 28{\cdot}86 \\
2\,O = & \underline{32} & \underline{16{\cdot}49} \\
 & 194 & 100{\cdot}00
\end{array}$$

$$\begin{array}{rl}
\log 9600 = & 3{\cdot}9823 \\
\log 194 = & \underline{2{\cdot}2878} \\
\log^{-1} & 1{\cdot}6945 = 49{\cdot}5.
\end{array}
\qquad
\begin{array}{rl}
\log 1000 = & 3{\cdot}0000 \\
\log 194 = & \underline{2{\cdot}2878} \\
\log^{-1} & {\cdot}7122 = 5{\cdot}15
\end{array}$$

$$\begin{array}{rl}
\log 5600 = & 3{\cdot}7482 \\
\log 194 = & \underline{2{\cdot}2878} \\
\log^{-1} & 1{\cdot}4604 = 28{\cdot}86
\end{array}
\qquad
\begin{array}{rl}
\log 3200 = & 3{\cdot}5051 \\
\log 194 = & \underline{2{\cdot}2878} \\
\log^{-1} & 1{\cdot}2173 = 16{\cdot}49.
\end{array}$$

(iv) 10 c.c. of hydrogen nitrate Δ 1·5 are warmed with copper and water, what volume of nitric oxide at 80° C. and 1000 m.m. is given off?

$$3Cu + 8HNO_3 = 3Cu\,2NO_3 + 4H_2O + 2NO.$$

$$\frac{10 \times 1{\cdot}5 \times 2 \times 30}{8 \times 63{\cdot}3} \times \frac{22{\cdot}32}{30} \times (1 + \alpha\,80) \times \frac{760}{1000},$$

$$\begin{array}{rlrl}
\log 30 & = 1{\cdot}4771 & \log 8000 & = 3{\cdot}9031 \\
\log 22{\cdot}32 & = 1{\cdot}3487 & \log 63{\cdot}3 & = 1{\cdot}8014 \\
\log (1 + \alpha\,80) & = {\cdot}1118 & & \overline{5{\cdot}7045} \\
\log 760 & = 2{\cdot}8808 & & \\
 & \overline{5{\cdot}8184} & &
\end{array}$$

$$\begin{array}{r}
5{\cdot}8184 \\
-\,5{\cdot}7045 \\
\hline
\end{array}$$

$$\log^{-1} \quad {\cdot}1139 = 1{\cdot}3 \text{ litres.}$$

(v) 0·5 gram of aniline, when burnt with cupric oxide, gave 36 c.c. of nitrogen measured over water at 15° C., under a pressure of 684 m.m. Find the percentage of nitrogen in the aniline.

The tension of aqueous vapour at 15° C. is 12·7 m.m.

$$\frac{36}{1000\,(1 + \alpha\,15)} \times \frac{684 - 12{\cdot}7}{760} \times \frac{28}{22{\cdot}32} \times \frac{100}{{\cdot}5};$$

$$\begin{array}{rlrl}
\log 36 & = 1{\cdot}5563 & \log (1 + \alpha\,15) & = {\cdot}0231 \\
\log 671{\cdot}3 & = 2{\cdot}8270 & \log 760 & = 2{\cdot}8808 \\
\log 28 & = 1{\cdot}4472 & \log 22{\cdot}32 & = 1{\cdot}3487 \\
 & \overline{5{\cdot}8305} & \log \;\; 5 & = {\cdot}6990 \\
 & & & \overline{4{\cdot}9516}
\end{array}$$

$$\begin{array}{r}
5{\cdot}8305 \\
-\,4{\cdot}9516 \\
\hline
\end{array}$$

$$\log^{-1} \quad {\cdot}8789 = 7{\cdot}567 \text{ per cent. of nitrogen.}$$

(vi) 4376 grams of potassium chlorate are heated, what volume of oxygen measured over water at 25° C. and 684 m.m. is given off?

$$KClO_3 = KCl + O_3.$$

The tension of aqueous vapour at 25° C. is 23·6 m.m.

$$\frac{4376 \times 48}{122{\cdot}6} \times \frac{22{\cdot}32}{32} \times (1 + \alpha\, 25)\, \frac{760}{684 - 23{\cdot}6},$$

$$\begin{array}{lrl}
\log 4376 & = 3{\cdot}6411 & \qquad \log 122{\cdot}6 = 2{\cdot}0885 \\
\log \ \ 48 & = 1{\cdot}6812 & \qquad \log \ \ 32 \ \ = 1{\cdot}5051 \\
\log 22{\cdot}32 & = 1{\cdot}3487 & \qquad \log 660{\cdot}4 = \underline{2{\cdot}8198} \\
\log (1 + \alpha 25) & = \ {\cdot}0382 & \qquad \qquad \quad \ \ 6{\cdot}4134 \\
\log \ \ 760 & = \underline{2{\cdot}8808} & \\
 & 9{\cdot}5900 & \\
 & \underline{-\,6{\cdot}4134} & \\
\log^{-1} & 3{\cdot}1766 = 1502 \text{ litres nearly.} &
\end{array}$$

(vii) Determine the vapour-density of camphor from the following results due to Dumas.

The volume of the globe was 295 c.c., and its increase in mass $(W - w)$, when filled with camphor-vapour, was 0·708 grams.

The temperature of the air was 13·5° C., and of the bath 239° C.

The barometer stood at 742 m.m.

The formula of camphor is $C_{10}H_{16}O$, and hence its density is 76 by theory.

$$D = \frac{{\cdot}708 + \dfrac{295 \times {\cdot}001293 \times 742}{(1 + \alpha 13{\cdot}5) \times 760}}{295 \times \dfrac{(1 + {\cdot}00003 \times 239) \times {\cdot}0000896 \times 742}{(1 + {\cdot}00003 \times 13{\cdot}5) \times (1 \times \alpha 239) \times 760}}$$

$$\log \frac{\cdot 001293}{(1+\alpha 13\cdot 5)760} = \bar{6}\cdot 2100$$

$$\log 295 = 2\cdot 4698$$

$$\log 742 = 2\cdot 8704$$

$$\log^{-1} \quad \bar{1}\cdot 5502 = \cdot 355$$ mass of air in globe

$$\underline{\cdot 708}$$

$$1\cdot 063$$ mass of camphor vapour.

If the volume of the globe at 13·5° C. be 1 it becomes at 239° C.

$$\frac{(1+00003\times 239)}{(1+00003\times 13\cdot 5)} = 1\cdot 007 \text{ nearly.}$$

$$\log 295 = 2\cdot 4698$$

$$\log 742 = 2\cdot 8704$$

$$\log \cdot 0000896 = \bar{5}\cdot 9523$$

$$\log 1\cdot 007 = \underline{\cdot 0029}$$

$$1\cdot 2954$$

$$\underline{-3\cdot 1543}$$

$$\bar{2}\cdot 1411$$ log of mass of an equal volume of hydrogen.

$$\log 760 = 2\cdot 8808$$

$$\log (1+\alpha 239) = \underline{\cdot 2735}$$

$$3\cdot 1543$$

$$\log \text{ of } 1\cdot 063 = \cdot 0265$$

$$\underline{-\bar{2}\cdot 1411}$$

$$\log^{-1} \quad 1\cdot 8854 = 76\cdot 8$$ density of camphor vapour.

Hence camphor vapour is 5·32 times heavier than air.

*THE REDUCTION OF EXPERIMENTAL RESULTS.

(35) THE DIFFERENT KINDS OF ERRORS.

An experiment is always liable to errors caused by mistakes, such as misreading the value of a weight in the pan of a balance, or the number marked on the graduation of a measure.

Constant errors caused by imperfections in the instruments or in the observer also occur, such as a weight not really being of the value marked upon it, or an observer constantly adding an excess of a precipitant from inability to detect the first trace of a precipitate.

Errors of this sort can only be lessened or removed by practice on the part of the observer, by care in testing the instruments used, and by varying the form of the experiments.

But besides these every experiment is affected by so-called accidental errors, which arise from momentary changes in the instruments, or from the want of absolute accuracy in the eye or hand of the observer.

Thus, in reading a standard barometer the same result is rarely obtained three times in succession.

Accidental errors may however be to some extent corrected by repeating an experiment a sufficient number of times, for it is probable, that if a large number of observations of exactly the same kind be made, about half will be in excess and half in defect of the true value. Hence if the results of a number of observations be added together and the sum be divided by the number of the observations, the average or arithmetical mean obtained is probably more near the correct result than any one result taken hap-hazard. And it is possible to determine by calculation how far this mean probably is from the true result.

Further, if, when the condition of a substance is altered in one respect, it is found to alter simultaneously in another, it is often required given certain changes in the first condition to find the most probable values of changes in the second condition which have been determined by experiment, and also to calculate values for the second condition which have not been determined experimentally.

There are two methods of effecting this, the one geometrical (the Graphical Method), the other analytical (the Method of Interpolation).

(36) THE METHOD OF LEAST SQUARES.

In any series of equally precise observations upon a single quantity, the most probable value is the arithmetical mean obtained by adding all the results together and dividing the sum by the number of observations.

To ascertain the trustworthiness of this mean result:—

(i) Find the residuals, these are the excess or defect of each result from the mean.

(ii) Square the residuals, and add the squares together.

(iii) Divide by the number of observations multiplied by one less than the number of observations, and take the square root of the quotient. This gives the mean error of the mean result.

(iv) Multiply the mean error of the mean result by 0·6745, and the probable error of the mean result is obtained.

The probable error of the mean result is a test of its trustworthiness, since it is a probability of $\frac{1}{2}$, or the odds are even, that the true result lies between the mean result + or − the probable error.

Thus 100 grams of tin, when oxidized by hydrogen nitrate, give according to

Berzelius	127·2	grams	of	stannic oxide.
Mulder	127·56	,,	,,	,,
Dumas	127·11	,,	,,	,,

Hence, assuming that the result obtained by each chemist is of equal value, 100 grams of tin most probably give $\frac{381 \cdot 87}{3} = 127 \cdot 29$ grams of stannic oxide.

The probable error of this mean result, n the number of experiments being 3, is:—

$$0 \cdot 6745 \frac{\sqrt{\text{sum of the squares of the residuals}}}{\sqrt{n(n-1)}}.$$

		v	v^2
− 127·29 +	127·2	− ·09	·0081
	127·56	+ ·27	·0729
	127·11	− ·18	·0324
			·1134

$$\therefore \text{ the probable error is } \cdot 6745 \frac{\sqrt{\cdot 1134}}{\sqrt{3 \times 2}} = \cdot 09.$$

This result is written 127·29 ± ·09, which means that it is an equal chance that the true value lies between 127·2 and 129·38 grams.

The precision of the mean increases as the square root of the number of observations.

If the values of the results are not all equal, each result must be multiplied by a number expressing its worth relatively to the others called its "weight." Or the calculation is effected as though each experiment had been repeated a number of times corresponding to its assumed accuracy.

The mean of the measured quantity is found by multiplying each observation by its weight, and dividing the sum of the products by the sum of the weights.

$$Z = \frac{g_1M_1 + g_2M_2 + g_3M_2 + \&c.}{g_1 + g_2 + g_3 + \&c.}.$$

The probable error of this general mean is

$$\frac{0{\cdot}6745\sqrt{g_1v_1^2 + g_2v_2^2 + g_3v_3^2 + \&c.}}{\sqrt{g_1 + g_2 + g_3 + \&c.}\sqrt{n-1}}.$$

Thus the quantity of hydrogen sulphate in 1 c.c. of a solution was determined by three different methods :—

(α) By barium chloride as ·0847 gram, weight 3.
(β) By sodium " as ·085 gram, weight 2.
(γ) By sodium carbonate as ·084 gram, weight 1.

g		v	gv^2
3	·0847	·0000	·00000000
2	·085	·0003	·00000018
1	·084	·0007	·00000049
6	$Z =$ ·0847		·00000067

The probable error is $\dfrac{{\cdot}6745\sqrt{{\cdot}00000067}}{\sqrt{6}\sqrt{2}} = {\cdot}0002.$

And the result is ·0847 ± ·0002, or it is an equal chance that the true result lies between ·0845 and ·0849.

(37) THE GRAPHICAL METHOD.

The graphical method enables an experimenter to compare a number of results in which two quantities vary simultaneously, to find the most probable value of each result, and to trace out a general law which serves to determine intermediate values of the results.

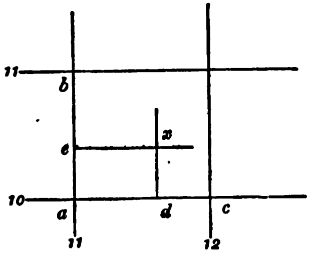
A sheet of copper or paper is ruled into a large number of equal squares, and commencing with the left hand bottom corner which is called the origin, the lines are numbered consecutively according to the two quantities which vary simultaneously.

Along the bottom line which is spoken of as the x-axis, the variable is measured, and portions cut off from it are called abscissæ. The variant is measured along the vertical line or y-axis, lengths parallel to which are called ordinates.

To express a result the value of x is measured parallel to or along the x-axis, and the corresponding value of y is measured parallel to or along the y-axis. Lines are drawn through these points parallel to the y-axis and to the x-axis respectively, and their point of intersection is the required point.

Thus if it be required to express a value of $x = 11{\cdot}6$ and $y = 10{\cdot}4$ or as it is usually written to find the point (11·6, 10·4), the point must evidently lie in the small square contained by the lines drawn through the abscissæ 11 and 12, and through the ordinates of length 10 and 11. By means of a dividing machine or pair of compasses and ruler, *ad* is cut off equal to $\frac{6}{10}$ of *ac*, and *ae* equal to $\frac{4}{10}$ of *ab*.

Then *ex* and *dx* are drawn parallel to *ac* and *ab* respectively, the point of intersection (x, y) is the required point (11·6, 10·4).



In exactly the same way all the other experimental results (x_1, y_1) (x_2, y_2) (x_3, y_3) &c. are expressed on the paper, and a permanent record of all the experiments is thus obtained.

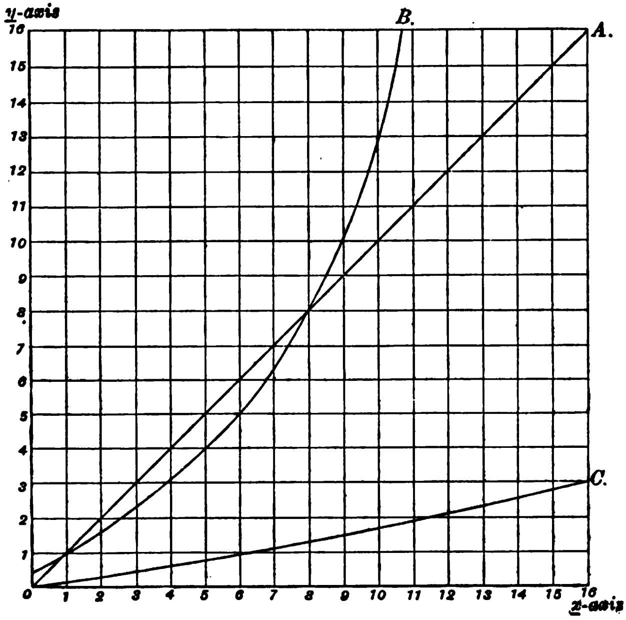
But further, if the results are sufficiently close together it may in most cases be assumed that no sudden change of value occurs between them, and therefore that the true values would lie on a continuous line, passing among the points expressing the experimental results. This line in most cases is either a straight line or a continuous curve, passes through some of the points which have been experimentally determined, and leaves about an equal number of these points above and below it.

Such a continuous line then drawn by the free hand shows the most probable value of the experimental results, since its position at any point is determined not by one but by a considerable number of experiments; it also enables the value of the result for any intermediate value of the variable, which has not been determined by experiment, to be obtained by direct measurement, for it in fact expresses the probable position of all the loci, which would be obtained were the experiments made infinite in number by taking infinitesimal changes of the variable.

Thus *OA* expresses the increase in volume of 273 volumes of gas at 0° C. when gradually heated to 16° C.

OB shows the number of grams of nitre dissolved by 100 grams of water from 0° C. to 106° C. (20 grams of nitre are expressed by 1 of ordinate, and 10° C. by 1 of abscissa).

And *OC* shows the expansion of 100 volumes of mercury at 0° C. when heated to 160° C. (1 of ordinate expresses 1 volume of mercury, and 1 of abscissa expresses 10° C.).



(38) INTERPOLATION.

When two values vary simultaneously it frequently happens that, having for a number of values of one variable the corresponding values of the other variable, it is required to determine the value of the second variable corresponding to some intermediate value of the first variable. In simple cases this is effected with sufficient accuracy by assuming that the change in value of one variable is proportional to the change in value of the other variable.

Thus, if 4100 volumes of gas at 100° C. become 5200 volumes at 200° C. to determine the volume of the gas at 150° C.

total change in temp. : partial change in temp.
:: total change in vol. : partial change in vol.

$$200-100 \quad : \quad 50$$

$$:: \quad 5200-4100 \quad : \quad x$$

$$x=\frac{1100\times 50}{100}=550.$$

Hence the volume at 150° C. will be 4100 + 550 = 4650 volumes.

But in complicated cases, especially when the intervals are large, the method by simple proportion becomes so inaccurate that it has to be replaced by another.

The most simple form of the problem is—given that a series of consecutive equidistant values of one variable x_0, x_1, x_2, x_3, &c. make the second variable have the values u_0, u_1, u_2, u_3, &c. to find the value of u_x when x lies between x_0 and x_1.

Write the values of the first variable in a column, and near them the corresponding values of the second variable. Subtract each value of the second variable from the succeeding one, and write these differences also in a column. Subtract each difference from the succeeding one to obtain a column of second differences, and in like manner if necessary obtain columns of third and fourth differences.

These differences are signified by Δu, $\Delta^2 u$, $\Delta^3 u$, $\Delta^4 u$, &c.

The value of u_x can then be found from the equation:—

$$u_x = u_0 + x\Delta u_0 + \frac{x(x-1)}{1.2}\Delta^2 u_0 + \frac{x(x-1)(x-2)}{1.2.3}\Delta^3 u_0 + \frac{x(x-1)(x-2)(x-3)}{1.2.3.4}\Delta^4 u_0 + \&c.$$

For the greatest accuracy the differences must be taken until they become constant for all values of u, that is, until each number in the column is identical.

Thus, to determine the tension of sulphur vapour at 440° C. from the tensions at the following temperatures:—

x^0 C.	u	Δu	$\Delta^2 u$	$\Delta^3 u$
400	329			
		451		
450	780		404	
		855		193
500	1635		597	
		1452		
550	3087			

The difference (x) between 400° C. and 440° C. is $\frac{4}{5}$ of the difference between 400° C. and 450° C. Hence the formula becomes;

$$u_x = 329 + \tfrac{4}{5} \times 451 + \tfrac{4}{5}\left(-\tfrac{1}{10}\right) 404 + \tfrac{4}{5}\left(-\tfrac{1}{10}\right)\left(-\tfrac{2}{5}\right) 193.$$
$$= 329 + 360{\cdot}8 - 32{\cdot}32 + 6{\cdot}176.$$
$$u_x = 663{\cdot}65 \text{ m.m.}$$

The tension at 440° C. found by experiment is 663·11 m.m. Had the ordinary mean only been taken, the result would have been found to be $329 + 360{\cdot}8 = 689{\cdot}8$ m.m.

Again, to find the tension of aqueous vapour at 11° C. having given:—

x^0 C.	u	Δu	$\Delta^2 u$	$\Delta^3 u$
10	9·165			
		3·524		
15	12·699		1·158	
		4·692		·309
20	17·391		1·467	
		6·159		
25	23·550			

The difference (x) for 1° C. is $\frac{1}{5}$ of the difference for 5° C., hence,

$$u_x = 9{\cdot}165 + \tfrac{1}{5} \times 3.524 + \tfrac{1}{5}\left(-\tfrac{2}{5}\right) \times 1{\cdot}158 + \tfrac{1}{5}\left(-\tfrac{2}{5}\right)\left(-\tfrac{3}{5}\right) \times {\cdot}309.$$

$$= 9{\cdot}165 + {\cdot}705 - {\cdot}093 + {\cdot}015.$$

$$u_x = 9{\cdot}792 \text{ m.m.}$$

A simple interpolation formula is of great use in reducing observations with the spectroscope from angular or scale-readings to wave-lengths.

If lines in a spectrum, which are tolerably close together, are found to have the scale-readings n_1, n_2, n_3, and the wave-lengths λ_1, λ_2, λ_3, these values are connected by the equation,

$$\frac{n_3 - n_1}{\lambda_1^2} + \frac{n_1 - n_3}{\lambda_2^2} + \frac{n_2 - n_1}{\lambda_3^2} = 0,$$

from which, if n_1, n_2, n_3 are determined by observation and the wave-lengths of two of the lines are known, the wave-length of the third line can be calculated.

Thus in the case of the three brightest lines of magnesium,

Scale-readings.	Wave-lengths.
74·5	5183
74·8	?
75·0	5167

$$\lambda_2^2 = \frac{n_3 - n_1}{\frac{n_2 - n_1}{\lambda_3^2} + \frac{n_3 - n_2}{\lambda_1^2}} = \frac{\cdot 5}{\frac{\cdot 3}{(5167)^2} + \frac{\cdot 2}{(5183)^2}}$$

$$= \frac{5\,(5167)^2\,(5183)^2}{3\,(5183)^2 + 2\,(5167)^2}.$$

$\therefore\ \lambda_2 = 5173.$

The problem becomes much more complicated, when it is required to find a formula to express the results of all experiments, which have been or might be made on any given change.

No general rules including all cases can be given. If nothing suggests any one form of equation as more probable than another, it is usually most convenient to assume an equation of the form

$$y = a + bx + cx^2 + dx^3 + \&c.,$$

and to determine the constants a, b, c and d from the experimental results, since equations of this form are found to include most of the more commonly occurring cases in Chemistry and Physics.

To determine the constants widely separated values x_1, x_2, x_3, of x are taken and y_1, y_2, y_3 are determined in each case; another experiment in which if possible x is made equal to 0 serves to determine a.

Now writing $y_1 - a = a_1$, $y_2 - a = a_2$, $y_3 - a = a_3$.

$$a_1 = bx_1 + cx_1^2 + dx_1^3.$$
$$a_2 = bx_2 + cx_2^2 + dx_2^3.$$
$$a_3 = bx_3 + cx_3^2 + dx_3^3.$$

From these three equations the three unknowns b, c, and d can be determined by any of the ordinary methods, or by the method of cross multiplication, which gives:—

$$b = \frac{a_1(x_2^2x_3^3 - x_2^3x_3^2) + a_2(x_3^2x_1^3 - x_3^3x_1^2) + a_3(x_1^2x_2^3 - x_1^3x_2^2)}{x_1(x_2^2x_3^3 - x_2^3x_3^2) + x_2(x_3^2x_1^3 - x_3^3x_1^2) + x_3(x_1^2x_2^3 - x_1^3x_2^2)}.$$

$$c = \frac{a_1(x_2^3x_3 - x_2x_3^3) + a_2(x_3^3x_1 - x_3x_1^3) + a_3(x_1^3x_2 - x_1x_2^3)}{x_1^2(x_2^3x_3 - x_2x_3^3) + x_2^2(x_3^3x_1 - x_3x_1^3) + x_3^2(x_1^3x_2 - x_1x_2^3)}.$$

$$d = \frac{a_1(x_2x_3^2 - x_2^2x_3) + a_2(x_3x_1^2 - x_3^2x_1) + a_3(x_1x_2^2 - x_1^2x_2)}{x_1^3(x_2x_3^2 - x_2^2x_3) + x_2^3(x_3x_1^2 - x_3^2x_1) + x_3^3(x_1x_2^2 - x_1^2x_2)}.$$

Thus, to find the equation representing the solubility of Magnesium sulphate $MgSO_4 . 7H_2O$ in water at different temperatures.

100 grams of water at 0° C. dissolve 25·8 grams of the salt
10° C. „ 30·5 „ „
90° C. „ 70·3 „ „

$$y = a + bt + ct^2 + \&c.$$

$$30{\cdot}5 = 25{\cdot}8 + 10b + 100c.$$

$$70{\cdot}3 = 25{\cdot}8 + 90b + 8100c.$$

$$\therefore\ 90b + 8100c = 44{\cdot}5$$

$$90b + 900c = 4{\cdot}5$$

$$c = -\frac{\cdot 5}{7200}$$ which may be neglected.

$$b = 0{\cdot}493.$$

$$\therefore\ y = 25{\cdot}8 + 0{\cdot}493t.$$

To ascertain the truth of the formula found, the amount of salt dissolved at some intermediate temperatures is calculated from the formula and determined by experiment.

° C.	y by exp.	y by calcul.
30	39·8	40·6
60	55·9	55·4
80	65·1	65·2

Since the results agree with fair accuracy, the equation found is probably correct.

Again, to find a formula for the volume occupied by one volume of mercury at 0° C. when heated to any temperature below 300° C. By experiment (Regnault):—

1 volume of mercury at 0° C. becomes at 10° C. 1·001792.
100° C. 1·018153.
200° C. 1·036811.
300° C. 1·055973.

Assume $y = a + bt + ct^2 + dt^3$ where $a = 1$.

$$1{\cdot}001\,792 = 1 + 10b + 100c + 1000d \ldots\ldots\ldots\ldots(\text{i}).$$
$$1{\cdot}018\,153 = 1 + 100b + 10\,000c + 1\,000\,000d \ldots\ldots(\text{ii}).$$
$$1{\cdot}036\,811 = 1 + 200b + 40\,000c + 8\,000\,000d \ldots\ldots(\text{iii}).$$
$$1{\cdot}055\,973 = 1 + 300b + 90\,000c + 27\,000\,000d \ldots(\text{iv}).$$

Multiplying (i) by 10 and subtracting it from (ii).

$$\cdot 000\,233 = 9\,000c + 90\,000d,$$
$$\therefore \cdot 000\,000\,026 = c + 100d.$$

Multiplying (iii) by 3 and subtracting it from (iv) multiplied by 2,

$$\cdot 001\,513 = 60\,000c + 30\,000\,000d.$$
$$\therefore \cdot 000\,000\,025\,2 = c + 500d.$$

$\therefore d = - \cdot 000\,000\,000\,002$ which may be neglected.

$$\therefore c = \cdot 000\,000\,0252,$$
$$\text{and } b = \cdot 000\,179\,01,$$

and the required equation is

$$y = 1 + \cdot 000\,179\,01t + \cdot 000\,000\,025\,2t^2.$$

Regnault gives

$$y = 1 + \cdot 000\,179\,006\,6t + \cdot 000\,000\,025\,231t^2.$$

Again, to find the mass of ammonia dissolved by 1000 grams of water at any temperature below 100° C.

1000 grams of water at

0° C.	dissolve	899	grams	of ammonia.
10° C.	,,	684	,,	,,
50° C.	,,	284	,,	,,
100° C.	,,	74	,,	,,

Write the three equations in the form $y = a + bt + ct^2 + dt^3$; subtract the value of a, and divide by the value of t.

$$-21{\cdot}5 = b + 10c + 100d \ldots\ldots\ldots\ldots\ldots \text{(i)}$$

$$-12{\cdot}3 = b + 50c + 2500d \ldots\ldots\ldots\ldots \text{(ii)}$$

$$-8{\cdot}25 = b + 100c + 10000d \ldots\ldots\ldots\ldots \text{(iii)}.$$

Subtract (i) from (ii) and divide by 4

$$2{\cdot}3 = 10c + 600d.$$

Subtract (ii) from (iii) and divide by 5

$$\cdot 81 = 10c + 1500d,$$

$$\therefore \; -1{\cdot}49 = 900d.$$

$$d = -\;\cdot 00166$$

$$c = \;\cdot 3296$$

$$b = -24{\cdot}63.$$

Hence the required equation is

$$y = 899 - 24{\cdot}63t + 0{\cdot}3296t^2 - 0{\cdot}00166t^3.$$

Should the accuracy of the observational equations be doubtful, to obtain the most probable values of b, c, and d from them, it is advisable to proceed as follows:—

Reduce any number of observational equations to the form:—

$$a_1 = bx_1 + cx_1^2 + dx_1^3.$$

$$a_2 = bx_2 + cx_2^2 + dx_2^3.$$

$$a_3 = bx_3 + cx_3^2 + dx_3^3.$$

$$\ldots = \ldots + \ldots + \ldots$$

Multiply each equation by the coefficient of b in it, and add all the equations together. The resulting equation is called the normal equation for b, and when solved will give the most probable value for b. Proceed in the same manner, multiplying by their coefficients respectively, to find normal equations for c and d.

$$a_1x_1 + a_2x_2 + a_3x_3$$
$$= (x_1^2 + x_2^2 + x_3^2)\,b + (x_1^3 + x_2^3 + x_3^3)\,c + (x_1^4 + x_2^4 + x_3^4)\,d \ldots \text{(i)}.$$

$$a_1x_1^2 + a_2x_2^2 + a_3x_3^2$$
$$= (x_1^3 + x_2^3 + x_3^3)\,b + (x_1^4 + x_2^4 + x_3^4)\,c + (x_1^5 + x_2^5 + x_3^5)\,d \ldots \text{(ii)}.$$

$$a_1x_1^3 + a_2x_2^3 + a_3x_3^3$$
$$= (x_1^4 + x_2^4 + x_3^4)\,b + (x_1^5 + x_2^5 + x_3^5)\,c + (x_1^6 + x_2^6 + x_3^6)\,d \ldots \text{(iii)}.$$

These normal equations when solved by any method, that of cross multiplication being usually the shortest, give the most probable values for b, c, and d; whence the required equation is obtained.

Occasionally other formulæ have to be used, but no general rules can be given for obtaining them.

Thus at any low temperature t° C. the tension of aqueous vapour in m.m. of mercury is

$$F = 0{\cdot}013 + 0{\cdot}2968\,(1{\cdot}089)^t.$$

And one volume of water at 4° C. becomes at any other temperature t° C.

$$V = 1 + 0{\cdot}000\,008\,38\,(t-4)^2 - 0{\cdot}000\,000\,379\,(t-4)^{26} + 0{\cdot}000\,000\,022\,4\,(t-4)^3.$$

EXAMPLES.

CHAPTER I.

General Measures.

(*See Sects.* (7), (8), (9), *Table II.*)

1. A cistern is 2 metres long, 1·5 m. wide and 1 m. deep; how many litres of water will it contain?

2. How many pounds Troy are there in a kilogram?

3. If the value of g (the attractive force of gravity) at London is 32·1908 feet, what is it in metres?

4. It is 92000000 miles to the sun; how many kilometres is it?

5. Light travels 192000 miles a second; how many kilometres per second is that?

6. Sound travels 1130 feet in a second; how many metres per second is that?

7. Find the mass of a block of flint glass (Δ 3·5) 10 centimetres long and wide, and 2·857143 c.m. thick.

8. A block of steel (Δ 7·8) is 10 c.m. square and 1·8315 c.m. thick; find its mass.

9. Find the mass in tons of a ship which displaces 64240 cubic feet of sea-water (Δ 1·026).

10. The velocity of light is $3{\cdot}004 \times 10^8$ metres per second, and it takes 8 minutes 13 seconds to pass from the sun to the earth. How many miles is the sun distant from the earth?

11. The latitude of Greenwich is $51^\circ 28' 40''$. Express this angle in seconds, and in degrees and decimals of a degree.

12. A geographical mile or knot is the distance subtended at the equator by an angle of $1'$ at the centre of the earth. How many knots is it round the equator?

13. According to Bessel the polar radius of the earth is 20853657 feet, and the equatorial radius 20923600 feet.

How many geographical miles in length is the great circle passing through the poles and Greenwich?

14. Using the data of the last question, find the volume of the earth in cubic feet, and if the density be 5·67 its mass in pounds.

15. A pressure of 1000 lbs. per square inch is how many kilos. per square millimetre?

16. What is the mass of a cubic metre of hematite (Δ 5·25)?

17. What is the mass of a cubic kilometre of sea-water (Δ 1·02)?

18. A nautical fathom is 6·0864 feet, what is its value in metres?

19. A piece of porcelain (Δ 2·3) is 10 c.m. square and 8·696 c.m. thick; find its mass in grams.

20. A round dolomite pillar (Δ 2·9) 1 m. across and 10 m. high weighs how many kilograms?

21. Find the volume of 1000 grams of sea-water (Δ 1·026).

22. Find the mass of a cubic metre of anthracite (Δ 1·4).

23. Find the mass of a glass (Δ 2·45) cylinder 2 decimetres high and 1 d.m. across.

24. How many tons does a block of granite (Δ 2·7) 10 by 3 by 2 metres weigh?

25. The great pyramid (Δ 2·5) is 145 m. high, and the side of its square base is 658·3 m.; find its mass in tonnes.

26. The surface of a sphere is 480 square yards; find its volume in cubic feet.

27. A glass ball, weighing 7·7158 grams, 2 c.m. in diameter, just floats in a liquid. Find the density of the liquid.

28. A quantity of silver when placed in one pan of an untrue balance weighed 5 grams, but when placed in the other pan it weighed 6 grams. Find the true mass of the silver.

29. The value found by Joule for the mechanical equivalent of heat was 772 foot-lbs. per 1° F. What is the value of J., taking as units 1° C., the kilogram, and the metre?

30. A glass ball counterpoised in air appeared to lose 5·6 grams when plunged into water, and 5·09 grams when plunged into turpentine. A crystal of copper sulphate, which weighed 11·69 grams in air, when plunged into turpentine appeared to lose 4·63 grams. Find the density of the turpentine and of the copper sulphate.

31. When the mercury (Δ 13·596) barometer stands at 76 c.m., how high will one of glycerin (Δ 1·27) stand?

32. When the mercury (Δ 13·596) barometer stands at 760 m.m., how high would one of hydrogen sulphate (Δ 1·842) stand?

CHAPTER II.

MOLECULAR WEIGHTS.

(*See Sect.* **10.**)

1. FIND the molecular weight of (i) carbon monoxide CO, (ii) magnesia MgO, (iii) lime CaO, (iv) silica SiO_2, (v) alumina Al_2O_3.

2. Find the percentage of oxygen in each of the abovementioned bodies.

3. Find the molecular weight of (i) nitric oxide NO, (ii) sodium hydrate $HNaO$, (iii) ferric oxide Fe_2O_3, (iv) chromium trioxide CrO_3, (v) cadmium oxide CdO.

4. Find the molecular weight of (i) antimony pentoxide Sb_2O_5, (ii) silver arsenate Ag_3AsO_4, (iii) barium sulphate $BaSO_4$, (iv) lead nitrate $Pb2NO_3$, (v) potassium phosphate K_3PO_4.

5. Find the molecular weight of (i) zinc sulphate $ZnSO_4 . 7H_2O$, (ii) copper sulphate $CuSO_4 . 5H_2O$, (iii) sodium sulphate $Na_2SO_4 . 10H_2O$, (iv) nickel sulphate $NiSO_4 . 7H_2O$, (v) manganous sulphate $MnSO_4 . 4H_2O$.

6. Find the molecular weight of (i) alcohol C_2H_6O, (ii) ether $C_4H_{10}O$, (iii) hydrogen acetate $C_2H_4O_2$, (iv) hydrogen oxalate $C_2H_2O_4 . 2H_2O$, (v) hydrogen tartrate $C_4H_6O_6$.

7. Find the molecular weight of (i) glycerin $C_3H_8O_3$, (ii) turpentine $C_{10}H_{16}$, (iii) aniline C_6H_7N, (iv) hydrogen stearate $C_{18}H_{36}O_2$, (v) cane-sugar $C_{12}H_{22}O_{11}$.

8. Find the molecular weight of (i) potassium chlorate $KClO_3$, (ii) borax $Na_2B_4O_7 . 10H_2O$, (iii) strontium bromide $SrBr_2 . 6H_2O$, (iv) barium carbonate $BaCO_3$, (v) potassium dichromate $K_2Cr_2O_7$.

9. Find the molecular weight of (i) potassium ferrocyanide $K_4FeC_6N_6 . 3H_2O$, (ii) calcium fluosilicate $CaSiF_6$, (iii) sodium thiosulphate $Na_2S_2O_3 . 5H_2O$, (iv) microcosmic salt $NaNH_4HPO_4 . 4H_2O$, (v) sodium nitroprusside $Na_4FeC_{10}N_{10}(NO_2)_2 . 4H_2O$.

CHAPTER III.

TEMPERATURES.

(*See Sect.* 15.)

1. CONVERT from the Reaumur to the Centigrade scale:— (i) 36° R., (ii) 28° R., (iii) 76° R., (iv) 60° R., (v) 52° R.

2. Convert from the Centigrade to the Reaumur scale:— (i) 90° C., (ii) 15° C., (iii) 20° C., (iv) 55° C., (v) 30° C.

3. Convert from the Reaumur to the Fahrenheit scale:— (i) 56° R., (ii) 60·4° R, (iii) 41·7° R., (iv) – 6·6° R., (v) – 25·3° R.

4. Convert from the Fahrenheit to the Reaumur scale:— (i) 48° F., (ii) 129° F., (iii) 168° F., (iv) 210° F., (v) – 30° F.

5. Convert from the Centigrade to the Fahrenheit scale:— (i) 60·5° C., (ii) 40° C., (iii) 70° C., (iv) – 5° C., (v) – 36·6° C.

6. Convert from the Fahrenheit to the Centigrade scale:— (i) 207° F., (ii) 180° F., (iii) 114° F., (iv) 0° F., (v) – 30° F.

7. Convert from the Centigrade to the Fahrenheit scale:— (i) 643° C., (ii) 720° C., (iii) 860° C., (iv) 973° C., (v) 1000° C.

8. Convert from the Fahrenheit to the Centigrade scale:— (i) 674° F., (ii) 100° F., (iii) 463° F., (iv) 3478° F., (v) 2941° F.

9. Convert from the Centigrade to the absolute scale :— (i) 6° C., (ii) 80° C., (iii) – 40° C., (iv) – 14° C., (v) – 100° C.

10. Convert from the Fahrenheit to the absolute scale :— (i) 70° F., (ii) – 4° F., (iii) 104° F., (iv) 2000° F., (v) – 37° F.

11. Convert (i) 300°, (ii) 400°, (iii) 500° on the absolute scale into the Centigrade, Reaumur, and Fahrenheit scales.

12. Convert each of the following temperatures into the other two scales: 42° F., – 32° F., 327° R., – 2° R., 78° C., and 172° C.

CHAPTER IV.

THE VOLUME OF A MASS of GAS.

(*See Sects.* **14, 16.**)

1. 1000 c.c. of gas are heated from 0° C. to 39° C. Find the new volume.

2. 1000 c.c. of gas are heated from −39° C. to 52° C. Find the new volume.

3. The pressure on 10 c.c. of gas is 7 metres; if the pressure be reduced to 847 millimetres, what is the new volume?

4. 1000 c.c. of air at 13° C. occupy what volume at 65° C.?

5. If 300 c.c. of gas are measured off at 28° C., what will the volume become at −14° C.?

6. 155 litres of air at 150° C. are cooled to 0° C. Find the new volume.

7. A litre of gas is heated from 14° C. to 42° C. Find the new volume.

8. A litre of air at 39° C. is cooled to −26° C. Find the new volume.

9. 134 litres of air are heated from −30° C. to 60° C. Find the new volume.

10. 50 c.c. of gas at 10° C. occupy what volume at 24° C.?

11. 100 c.c. of air at 12° C. are heated until they occupy 145 c.c. Find the new temperature.

12. 1000 c.c. of air at – 31·2° R. are heated to 172·4° F. What is the new volume?

13. 320 c.c. of gas are measured off at 91° C. and 950 m.m. What is the normal volume?

14. 150 c.c. of gas are measured off at 10° C. and 500 m.m. What does the volume become at 16·4° C. and 520 m.m.?

15. 852 c.c. of air at 11° C. and 760 m.m. are heated to 27° C., the pressure being increased to 900 m.m. Find the new volume.

16. 542 c.c. of air at 269° C. and 900 m.m. are cooled to 51° C., the pressure being decreased to 666 m.m. Find the new volume.

17. 672 c.c. of air at – 49° C. and 1111 m.m. measure what at 357° C. and 1890 m.m.?

18. 700 c.c. of air at 77° C. and 1000 m.m. measure what at 163° C. and 872 m.m.?

19. 546 c.c. of gas at 17° C. and 760 m.m. are cooled to 0° C., the pressure being decreased to 600 m.m. Find the new volume.

20. 1234 c.c. of gas at – 39° C. and 500 m.m. are heated to 39° C., the pressure being increased to 617 m.m. Find the new volume.

21. A quantity of oxygen, which measures 230 litres at 14° C. and 740 m.m., will measure what at 0° C. and 760 m.m.?

22. What will 1000 c.c. of a normal gas become at 16·5° C. and 735 m.m.?

23. A flask, which will not bear a pressure of 1500 m.m., is filled with normal oxygen and heated. At what temperature will it explode?

24. A volume of gas at 10° C. is under the pressure of the atmosphere and 60 m.m. of mercury; what pressure is required in addition to the atmosphere to keep the volume constant at 300° C.?

25. At what temperature has air the same density as hydrogen at 0° C.?

26. 1234 c.c. of normal gas are cooled to – 52° C., the pressure being decreased to 617 m.m. Find the new volume.

27. 632 c.c. of air at 43° C. and 1000 m.m. are heated to 97° C., the pressure being decreased to 740 m.m. Find the new volume.

28. 146 litres of gas at 17° C. and 974 m.m. are heated to 51° C., the pressure being decreased to 760 m.m. Find the new volume.

29. 1000 c.c. of gas at 20° C. and 730 m.m. occupy what volume at 0° C. and 760 m.m?

30. 123 c.c. of gas at 247° C. and 800 m.m. are cooled to – 26° C., the pressure being decreased to 780 m.m. Find the new volume.

31. 1000 c.c. of air are heated from 0° C. to 72° C., the pressure being decreased from 600 m.m. to 400 m.m. Find the new volume.

32. 20 c.c. of hydrogen at 27° C. and 762 m.m. occupy what volume at – 23° C. and 1270 m.m?

CHAPTER V.

OXYGEN. O = 16.

N.B. *In working the easier sums 'two volumes'* (*Sect.* 18) *are taken as* 22·4 *litres, and the coefficient of expansion of a gas is taken as* $\frac{1}{273}$. *In the more difficult sums below the line two volumes are taken as* 22·32 *litres and* ·00367 *as the coefficient of expansion.*

1. 50 grams of potassium chlorate are heated; what mass of oxygen is given off?

$$KClO_3 = KCl + 3O.$$

2. What volume is occupied by 20 grams of oxygen (O_2)?

3. How much potassium chlorate is required to make 112 litres of oxygen?

$$KClO_3 = KCl + 3O.$$

4. What volume of oxygen can be obtained from 20 grams of manganese dioxide by heating it (*a*) alone?

$$3MnO_2 = Mn_3O_4 + O_2.$$

(*β*) with strong hydrogen sulphate?

$$MnO_2 + H_2SO_4 = MnSO_4 + H_2O + O.$$

5. What mass of oxygen can be obtained by heating 522 grams of manganese dioxide?

$$3MnO_2 = Mn_3O_4 + O_2.$$

6. How much manganese dioxide is required to make 10 litres of oxygen?

$$3MnO_2 = Mn_3O_4 + O_2.$$

7. What mass of oxygen (O_2) at 10° C. and 750 m.m. would fill a globe of 15 litres capacity?

8. What volume of oxygen can be made from 100 grams of mercuric oxide?

$$HgO = Hg + O.$$

9. On heating some potassium chlorate 298 grams of potassium chloride were left. What mass of chlorate was heated and what mass of oxygen was formed?

$$KClO_3 = KCl + 3O.$$

10. How much potassium chlorate is required to make 70 litres of oxygen?

$$KClO_3 = KCl + 3O.$$

11. What volume of oxygen at 21° C. and 380 m.m. can be obtained by heating 1000 grams of potassium chlorate?

$$KClO_3 = KCl + 3O.$$

12. What mass of oxygen would occupy 13 litres at 12° C.? And how much manganese dioxide must be heated to obtain it?

$$3MnO_2 = Mn_3O_4 + O_2.$$

13. 174 grams of manganese dioxide are heated; what volume of oxygen is given off?

$$3MnO_2 = Mn_3O_4 + O_2.$$

14. How much potassium chlorate will furnish sufficient oxygen to unite with the hydrogen evolved by the action of 200 grams of sodium upon water?

$$6Na + 6H_2O = 6HNaO + 3H_2.$$
$$3H_2 + 3O = 3H_2O.$$
$$KClO_3 = KCl + 3O.$$

15. 60 grams of mercuric oxide are heated; what volume of oxygen at 91° C. and 380 m.m. is given off?

$$HgO = Hg + O.$$

16. What volume of oxygen can be made from 100 grams of potassium chlorate?

$$KClO_3 = KCl + 3O.$$

17. A gram of bleaching powder is boiled with water and cupric oxide; what volume of oxygen at 14° C. is given off?

$$CaOCl_2 = CaCl_2 + O.$$

18. A quantity of barium dioxide is suspended in water and decomposed by carbon dioxide. If 19·7 grams of barium carbonate are formed, what volume of oxygen at 14° C. will be set free on boiling the solution of hydrogen dioxide?

$$BaO_2 + CO_2 + H_2O = BaCO_3 + H_2O_2.$$
$$H_2O_2 = H_2O + O.$$

19. 270 grams of mercuric oxide are heated; what volume of oxygen at 0° C. and 760 m.m. is given off? And what will the gas measure at 17° C. and 700 m.m.?

$$HgO = Hg + O.$$

20. What volume of oxygen, supposing that it remained gaseous, at – 140° C. and under the pressure of 245·2 metres of mercury, could be made from 613 grams of potassium chlorate?

$$KClO_3 = KCl + 3O.$$

21. If liquid oxygen has the density ·89, what would be the volume of the liquefied gas?

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22. What is the mass of 13 litres of oxygen (O_2) measured at 12° C.?

23. In one of Dumas and Boussingault's experiments the cupric oxide lost 59·789 grams, and 67·282 grams of water were formed. Calculate the atomic weight of oxygen.

$$CuO + H_2 = Cu + H_2O.$$

24. 10 grams of potassium dichromate are boiled with hydrogen sulphate; what volume of oxygen at 20° C. is given off?

$$K_2Cr_2O_7 + 4H_2SO_4 = K_2SO_4 + Cr_2 3SO_4 + 4H_2O + 3O.$$

25. What volume of liquid oxygen (Δ·89) could be obtained from 100 litres of the gas measured at 20° C.?

26. What is the mass of 556 c.c. of oxygen $(O)_2$ measured *over water* at 20° C. and 750 m.m.?

CHAPTER VI.

HYDROGEN. H = 1.

1. 100 grams of zinc are dissolved in dilute hydrogen sulphate, what volume of hydrogen is given off?

$$Zn + H_2SO_4 = ZnSO_4 + H_2.$$

2. What is the mass of 516 litres of hydrogen (H_2) measured at – 20° C. and 770 m.m.?

3. 100 grams of steam are passed over red-hot iron, what volume of hydrogen at 10° C. and 742 m.m. is formed?

$$4H_2O + 3Fe = Fe_3O_4 + 4H_2.$$

4. How many litres of hydrogen are obtained on dissolving 16 grams of magnesium in dilute hydrogen sulphate?

$$Mg + H_2SO_4 = MgSO_4 + H_2.$$

5. 50 litres of hydrogen at 17° C. and 800 m.m. are required, how much sodium must be thrown into water?

$$Na + H_2O = HNaO + H.$$

6. What volume will 1000 c.c. of hydrogen at 0° C. occupy at (α) 15° C., (β) 100° C., (γ) 300° C.?

7. What volume will 1000 c.c. of hydrogen at 100° C. occupy at (α) 0° C., (β) – 20° C., (γ) – 50° C.?

8. 4 litres of hydrogen are passed over heated cupric oxide, what loss of mass does the oxide undergo?

$$H_2 + CuO = Cu + H_2O.$$

9. Find the mass in grains of a cubic foot of normal hydrogen.

10. Find the mass in grains of a cubic inch of normal hydrogen.

11. 100 grams of levigated iron are dissolved in dilute hydrogen sulphate, what volume of hydrogen at 15° C. is given off?

$$Fe + H_2SO_4 = FeSO_4 + H_2.$$

12. 400 c.c. of hydrogen are measured off at 72° C. and 800 m.m., what is the normal volume?

13. Find the mass in grams of 10 gallons of hydrogen at 20° C.

14. Find the percentage of hydrogen in (α) hydrogen chloride HCl, (β) hydrogen sulphide H_2S, (γ) ammonia NH_3.

15. A spherical balloon 50 feet in radius would contain how many pounds of hydrogen and how many pounds of air?

16. A kilogram of potassium formate when heated with potassium hydrate would give what volume of hydrogen, supposing it were still gaseous, at $-140°$ C. and under a pressure of 494 metres of mercury?

$$CHKO_2 + HKO = K_2CO_3 + H_2.$$

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17. How much zinc is required to obtain 100 litres of hydrogen at 91° C. and 800 m.m.?

$$Zn + H_2SO_4 = ZnSO_4 + H_2.$$

18. How many c.c. of (α) magnesium (Δ1·74), (β) zinc (Δ7·2), (γ) iron (Δ7·8) must be dissolved in acid to give 50 litres of hydrogen at 15° C.?

$$[\mathrm{MgZnFe}] + \mathrm{H_2SO_4} = [\mathrm{MgZnFe}]\,\mathrm{SO_4} + \mathrm{H_2}.$$

19. 100 grams of potassium formate are heated with potassium hydrate, what volume of hydrogen at 15° C. and 790 m.m. is given off?

$$\mathrm{CHKO_2} + \mathrm{HKO} = \mathrm{K_2CO_3} + \mathrm{H_2}.$$

20. The hydrogen used at Woolwich has a lifting power of 71 lbs. per 1000 cubic feet, if the gas were pure what would the lifting power be?

21. What is the mass of a litre of hydrogen measured over water at 50° C. and 790 m.m.?

22. 2 grams of hydrogen mixed with 16 grams of oxygen are exploded in a closed vessel. Find the pressure inside the vessel at the moment of explosion. (The calorific power of the hydrogen is 34 462, and the specific heat of steam at constant volume is 0·3621.)

23. How much zinc must be dissolved in acid to make 5 cubic metres of hydrogen at 15° C. and 740 m.m.?

$$\mathrm{Zn} + \mathrm{H_2SO_4} = \mathrm{ZnSO_4} + \mathrm{H_2}.$$

24. Regnault found that one litre of normal
hydrogen weighs 0·089578 grams.
oxygen ,, 1·429802 grams...........(α).
nitrogen ,, 1·256167 grams..........(β).
carbon dioxide ,, 1·977414 grams...........(γ).

By dividing by the *exact* atomic or half molecular weight determine in each case the mass of a litre of hydrogen, and take the mean of the results.

CHAPTER VII.

WATER. $H_2O = 18$.

1. 10 grams of water are decomposed by an electric current, what volumes of hydrogen and of oxygen are evolved?

$$H_2O = H_2 + 0.$$

2. What is the density of hydrogen referred to water?

3. What volume is occupied by 100 grams of steam (H_2O) measured at 300° C.?

4. 100 c.c. of sodium (Δ·97) are thrown into water, what volume of hydrogen at 18° C. and 570 m.m. is given off?

$$Na + H_2O = HNaO + H.$$

5. How much potassium chlorate must be heated to give oxygen enough to combine with 100 litres of hydrogen?

$$3H_2 + 3O = 3H_2O.$$

$$KClO_3 = KCl + 3O.$$

6. What volume of oxygen at 12° C. and 762 m.m. is evolved on decomposing 10 grams of water by electricity?

$$H_2O = H_2 + O.$$

7. What is the volume of 1000 grams of (α) sea-water Δ 1·026 and (β) ice Δ ·924?

8. 1000 grams of sea-water (Δ 1·029) contain 35·9 grams of solid matter in solution. How many kilos. of solids are there in solution in a cubic kilometre of sea-water?

9. How many cubic feet are occupied by a ton of sea-water (Δ 1·029)?

10. 400 Troy ounces of water at 16° R. are mixed with 400 avoirdupois ounces at 95° F. Find the mass of the mixture in grams and its temperature Centigrade.

11. 500 c.c. of hydrogen at 39° C. are exploded with 500 c.c. of oxygen under a pressure of 332·5 m.m. What volume of which gas is left?

$$H_2 + O = H_2O.$$

12. How much water must be decomposed by electricity to form one litre of electrolytic gas at 15° C. and 740 m.m.?

$$H_2O = H_2 + O.$$

13. 2 grams of steam are passed over red-hot iron, what volume of hydrogen at 10° C. and 770 m.m. is formed?

$$4H_2O + 3Fe = Fe_3O_4 + 4H_2.$$

14. A block of ice (Δ ·92) weighs 280 kilos., find its volume.

15. If the density of ice be 0·92, what volume would 1000 c.c. of water at 4° C. occupy when frozen?

16. An iceberg (Δ ·92) floats in sea-water (Δ 1·027) with 30 000 cubic metres above the sea, what is the total volume of the berg?

17. Find the density of steam at 300° C. referred to air at 0° C.

18. 1 c.c. of water at 4° C. forms how many times its volume of steam at 300° C.?

19. The Great Eastern is 679 feet long, 82 feet broad, and 60 feet deep. Find each dimension in metres.

20. 100 grams of steam are passed over red-hot iron, what volume of hydrogen at 14° C. and 730 m.m. is formed?

$$4H_2O + 3Fe = Fe_3O_4 + 4H_2.$$

21. A tube containing cupric oxide, which weighed 105·6 grams, after being heated to redness in a current of hydrogen weighed 101·6 grams. The drying apparatus weighed 80·3 grams before and 84·8 grams after the experiment. How much oxygen unites with 1 part of hydrogen?

$$h + o = ho.$$

22. If 88·88 parts of oxygen combine with 11·11 parts of hydrogen to form water, and the equivalent of oxygen be 100, what is the equivalent of hydrogen?

$$h + o = ho.$$

23. Sea-water (Δ 1·026) contains 3 per cent. of sodium chloride $NaCl$; how much sodium is there in a cubic metre of sea-water?

24. 1000 grams of sea-water (Δ 1·027) contain 37 grams of salt (Δ 2·16). What contraction do 1000 c.c. of sea-water undergo during the solution of the salt?

25. If a cubic inch of water at 53° F. weighs 252·765 grains, and 1 c.c. of water at 4° C. weighs 1 gram, what volume will 1 000 000 c.c. of water at 4° C. occupy at 53° F.?

26. In one of Dumas' experiments to ascertain the composition of water by passing hydrogen over heated cupric oxide, the following results were obtained:—

	grams.
Mass of cupric oxide and tube before the experiment	334·598
" " " after " "	314·236
Mass of drying tubes before the experiment	426·358
" " " after " "	449·263

Calculate the percentage composition of water by mass.

27. A pound of steam at 374° F. occupies how many cubic feet ?

28. 100 grams of gypsum are heated, what volume of steam at 300° C. is given off?

$$CaSO_4 . 2H_2O = CaSO_4 + 2H_2O.$$

29. 100 grams of each variety of sodium carbonate (i) $Na_2CO_3 10H_2O$, (ii) $Na_2CO_3 . 8H_2O$, (iii) $Na_2CO_3 . 5H_2O$, (iv) $Na_2CO_3 . H_2O$ contain how many grams of water ?

30. 2 grams of silver oxide are thrown into hydrogen dioxide, what volume of oxygen at 13° C. is given off?

$$Ag_2O + H_2O_2 = Ag_2 + H_2O + O_2.$$

31. Pure hydrogen dioxide (Δ 1·455) gives how many times its volume of oxygen when boiled ?

$$H_2O_2 = H_2O + O.$$

32. A solution of hydrogen dioxide (Δ 1·455) gives twenty times its volume of oxygen when boiled, find its percentage composition by volume.

$$H_2O_2 = H_2O + O.$$

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33. What volume of oxygen at 10° C. can be obtained on boiling 10 grams of hydrogen dioxide ?

$$H_2O_2 = H_2O + O.$$

34. 100 grams of solution of hydrogen dioxide in water when boiled gave 5 litres of oxygen at 12° C. and 750 m.m. Find the percentage of hydrogen dioxide in the solution.

$$H_2O_2 = H_2O + O.$$

CHAPTER VIII.

NITROGEN. N = 14.

1. WHAT do 100 litres of nitrogen (N_2) weigh ?

2. 146 litres of nitrogen at 17° C. and 974 m.m. are heated to 51° C. the pressure being decreased to 760 m.m. Find the new volume.

3. What volume of nitrogen can be obtained from 10 grams of ammonium nitrite ?

$$NH_4NO_2 = 2H_2O + N_2.$$

4. 128 grams of ammonium nitrite are heated, what volume of nitrogen at 39° C. and 950 m.m. is given off ?

$$NH_4NO_2 = 2H_2O + N_2.$$

5. Find the percentage composition of ammonium nitrate NH_4NO_3.

6. What volume is occupied by 10 000 grams of hydrogen nitrate (Δ 1·5) ?

7. What volume of nitrous oxide can be obtained from 240 grams of ammonium nitrate ?

$$NH_4NO_3 = 2H_2O + N_2O.$$

8. How many pounds of hydrogen nitrate are obtained on distilling 400 pounds of sodium nitrate with hydrogen sulphate ?

$$2NaNO_3 + H_2SO_4 = Na_2SO_4 + 2HNO_3.$$

9. What volume of nitric oxide is obtained on dissolving 10 grams of copper in hydrogen nitrate?

$$3Cu + 8HNO_3 = 3Cu2NO_3 + 4H_2O + 2NO.$$

10. What volume of nitric oxide at 13° C. is obtained on dissolving 25 grams of copper in hydrogen nitrate?

$$3Cu + 8HNO_3 = 3Cu2NO_3 + 4H_2O + 2NO.$$

11. How much copper is required to form 10 litres of nitric oxide?

$$3Cu + 8HNO_3 = 3Cu2NO_3 + 4H_2O + 2NO.$$

12. How much ammonium nitrate is required to make 40 litres of nitrous oxide?

$$NH_4NO_3 = 2H_2O + N_2O.$$

13. 30 c.c. of nitrogen at 18° C. were measured in a tube. The barometer was 750 m.m. and the mercury stood at 120 m.m. in the tube. Find the normal volume of the gas and its mass in grams.

14. 127 grams of copper are dissolved in hydrogen nitrate, what volume of nitric oxide at 14° C. and 1000 m.m. is given off?

$$3Cu + 8HNO_3 = 3Cu2NO_3 + 4H_2O + 2NO.$$

15. What volume of hydrogen sulphate (Δ 1·84) must be distilled with 1 kilo. of sodium nitrate to make hydrogen nitrate, and what volume of hydrogen nitrate (Δ 1·5) will be formed?

$$NaNO_3 + H_2SO_4 = HNaSO_4 + HNO_3.$$

16. What is the mass of 100 litres of (α) nitrous oxide N_2O, and (β) nitric oxide NO?

17. What volume of nitric oxide is obtained on boiling 50 grams of hydrogen nitrate with an excess of acidified ferrous sulphate?

$$2HNO_3 + 3H_2SO_4 + 6FeSO_4 = 3Fe_23SO_4 + 4H_2O + 2NO.$$

18. What is the mass of 270 c.c. of nitrogen measured over water at 8° C. and 768 m.m.?

19. How much phosphorus can be burnt in 4 litres of nitrous oxide measured at 14° C.?

$$P_2 + 5N_2O = 5N_2 + P_2O_5.$$

20. 5 c.c. of mercury (Δ 13·55) are warmed with hydrogen nitrate, what volume of nitric oxide at 21° C. is evolved?

$$3Hg + 8HNO_3 = 3Hg2NO_3 + 4H_2O + 2NO.$$

21. 100 grams of cuprous oxide are warmed with dilute hydrogen nitrate, what volume of nitric oxide is evolved?

$$3Cu_2O + 14HNO_3 = 6Cu2NO_3 + 7H_2O + 2NO.$$

22. At 27° C. nitrogen tetroxide is 2·65 times as heavy as air, and at 180° C. it is 1·57 times as heavy, find the corresponding molecular weights.

23. Find the percentage composition of (α) nitrosyl chloride NOCl, and (β) nitryl chloride NO_2Cl.

24. What volume of chlorine at 15° C. must be passed over 20 grams of silver nitrate to obtain nitrogen pentoxide?

$$Cl_2 + 2AgNO_3 = 2AgCl + O + N_2O_5.$$

25. 4 litres of nitric oxide at 17° C. and 750 m.m. are passed over red-hot copper, what volume of nitrogen at 7° C. and 600 m.m. is formed?

$$2NO + 2Cu = 2CuO + N_2.$$

26. 3 grams of urea are warmed with potassium nitrite and hydrogen sulphate, what volume of nitrogen and of carbon dioxide is given off?

$$CON_2H_4 + N_2O_3 = 2N_2 + 2H_2O + CO_2.$$

27. 300 grams of dry lead nitrate are heated, what volume of nitrogen tetroxide at 100° C. is evolved?

$$Pb2NO_3 = PbO + O + 2NO_2.$$

28. Excess of carbon is thrown into 100 grams of fused potassium nitrate, what volume of nitrogen and of carbon dioxide is evolved?

$$4KNO_3 + 5C = 2K_2CO_3 + 2N_2 + 3CO_2.$$

29. A substance contains

Silver	78·25	per cent.
Nitrogen	10·15	,,
Oxygen	11·59	,,;

Find its formula.

30. What volume of ammonia is required to neutralize 10 grams of hydrogen chloride?

$$HCl + NH_3 = NH_4Cl.$$

31. What volume of ammonia at 15° C. and 740 m.m. could be obtained from 107 grams of ammonium chloride?

$$2NH_4Cl + CaO = CaCl_2 + H_2O + 2NH_3.$$

32. What is the mass of 2 litres of solution of ammonia (Δ ·88)?

33. What volume is occupied by 100 grams of ammonia NH_3?

34. 29 c.c. of ammonia are decomposed by a series of electric sparks, and the mixed gases are exploded with 30 c.c. of oxygen. What volumes of what gases remain?

$$2NH_3 = N_2 + 3H_2,$$
$$3H_2 + 3O = 3H_2O.$$

35. 2 grams of potassium are heated in ammonia, how much potassamide and what volume of hydrogen at 15° C. is formed?

$$K + NH_3 = KH_2N + H.$$

36. 10 grams of solution of ammonia when mixed with sodium hypobromite gave 1 litre of nitrogen at 7° C. Find the percentage of ammonia in the solution.

$$3NaBrO + 2NH_3 = 3NaBr + 3H_2O + N_2.$$

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37. What is the volume of 20 grams of ammonia (NH_3) at 12° C. and 730 m.m.?

38. 25·82 litres of nitric oxide diffuse through a certain apparatus in 50 minutes, what volume of hydrogen will diffuse under the same conditions?

39. A litre of hydrogen nitrate (Δ 1·4 containing 70 per cent. of real acid) is mixed with water and caused to act upon excess of copper. What volume of nitric oxide is given off?

$$3Cu + 8HNO_3 = 3Cu2NO_3 + 4H_2O + 2NO.$$

40. Excess of phosphorus is burnt in 10 litres of nitrous oxide, how much phosphorus pentoxide is formed, and what volume of nitrogen at 15° C. is left?

$$P_2 + 5N_2O = P_2O_5 + 5N_2.$$

41. 2 litres of nitryl chloride at 15° C. are passed over warm silver nitrate, how much nitrogen pentoxide is formed?

$$NO_2Cl + AgNO_3 = AgCl + N_2O_5.$$

42. Find the percentage composition of dimercurammonium iodide NHg_2I.

CHAPTER IX.

THE ATMOSPHERE.

A LITRE of normal air weighs 1·293 grams.

Air contains 23·8 per cent. of oxygen by mass, and 20·9 per cent. of oxygen by volume.

1. The pressure on 134 c.c. of air is increased from 480 m.m. to 1200 m.m. Find the new volume.

2. 476 c.c. of air are heated to 637° C. Find the new volume.

3. What is the mass of 500 cubic metres of air at 21° C.?

4. Find the mass of 640 c.c. of air measured at 546° C. and 712 m.m.

5. Westminster Hall is 290 feet long, 68 feet wide, and 110 feet high, how many tons of air does it contain?

6. The area of the basin of the Thames is 6000 square miles. A rainfall of 3·937 inches upon it is how many cubic metres of water?

7. 200 c.c. of air are measured at 20° C. and 740 m.m. What is the normal volume?

8. Find the normal volume of 250 litres of air measured at 30° C. and 740 m.m.

9. 20 c.c. of air are mixed with 30 c.c. of hydrogen and exploded, what volumes of what gases are left?

$$H_2 + O = H_2O.$$

10. On Oct. 14th, 1881, the pressure of the wind at Greenwich was 53 lbs. per square foot, how many grams per square centimetre is the pressure equivalent to? The pressure on the same day at Birkenhead was 77 lbs. per square foot, how many tons pressure was there on a wall 50 feet high and 60 feet long? If the rate of the wind was 65 miles per hour, how many feet per second was it?

11. How many pounds of air at 15° C. are there in a room 30 feet long, 22 feet wide, and 15 feet high? And what mass of oxygen is there in the air?

12. How many kilograms of air are there in a room 17 feet 6 inches long, 14 feet wide and 10 feet high?

13. It is calculated that the mass of the atmosphere is equal to that of 581 000 cubic kilometres of copper (Δ 8·9). Find the radius of an iron (Δ 7·8) sphere equal in mass to the atmosphere.

14. How much phosphorus must be burnt in what volume of air at 0° C. to make 15·8 litres of nitrogen at 13° C.?

$$P_2 + O_5 = P_2O_5.$$

15. What volume of air containing 21 per cent. of oxygen by volume is required to burn 248 grams of phosphorus?

$$P_2 + O_5 = P_2O_5.$$

16. How much phosphorus is required to remove the oxygen from a litre of air?

$$P_2 + O_5 = P_2O_5.$$

17. How much sulphur can be burnt in 20 litres of air at 26° C.?

$$S + O_2 = SO_2.$$

18. What volume of air at 21° C. must be passed over 100 grams of copper to convert them into cupric oxide?

$$Cu + O = CuO.$$

19. How much magnesium can be burnt in a globe containing 5 litres of air at 21° C. and 740 m.m.?

$$Mg + O = MgO.$$

20. How much moist iron can be oxidized by a cubic metre of air at 13° C.?

$$2Fe + 3O = Fe_2O_3.$$

21. In one of Dumas' experiments to determine the composition of air by passing it over heated copper:—

Mass of tube and copper before the experiment		120	grams.
„ „ „ after	„	121·15	„
Mass of the exhausted globe	„	852	„
„ globe and nitrogen	„	855·85	„

Calculate the percentage composition of air by mass and by volume.

22. How much phosphorus is required to remove all the oxygen from 100 litres of air at 15° C. and 740 m.m.?

$$P_2 + O_5 = P_2O_5.$$

23. An inch of rain is how many tons of water on an acre?

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24. 100 litres of air are passed over red-hot copper, how much does the copper increase in mass?

$$Cu + O = CuO.$$

25. A magnesium (Δ 1·74) wire is burnt in a cylinder of oxygen at 0° C. When the temperature has again fallen to 0° C., the length of wire burnt is found to be equal to the distance through which the water has risen in the cylinder. If the wire be 1 m.m. in diameter, find the radius of the cylinder.

$$Mg + O = MgO.$$

26. A mass of air a mile square and 100 feet thick is saturated with aqueous vapour at 50° F. (the tension is 9·165 m.m.). If the temperature fall to 41° F. (the tension is 6·534 m.m.), how many tons of water precipitate?

27. 1000 cubic metres of gas at 18° C. and 765 m.m. are put into a balloon of 1250 cubic metres capacity. After ascending to a certain height the temperature is found to be 8° C. and the balloon is fully distended. Find the height of the barometer in the balloon and its distance from the earth.

28. 500 grams of carbon are burnt in 60 cubic metres of air free from carbon dioxide at 14° C. Find the percentage of nitrogen, oxygen, and carbon dioxide in the air after the experiment.

$$C + O_2 = CO_2.$$

29. 146 c.c. of air at 10° C. and 730 m.m. are measured over water, what would the dry normal air measure?

30. A vessel of water at 99° C., weighing when reduced to water 50 kilos., was placed in a room 10 m. each way containing air at 0° C. and 760 m.m., the walls of which were impervious to heat. Find the temperature of the air and the increase in pressure on each sq. c.m. of the surface of the room.

CHAPTER X.

CARBON. $C = 12$.

1. A diamond ($\Delta 3{\cdot}5$) weighs 7 grams, what is its volume?

2. The density of coal is 1·257. (*a*) How many cubic feet are occupied by a ton of coal? (*β*) What does a cubic yard of coal weigh?

3. How many pencil-leads 2 m.m. square and a decimetre long can be cut from a kilogram of graphite ($\Delta 2{\cdot}25$)?

4. The specific heat of graphite is ·198, what is its probable atomic weight?

5. Find the mass of 100 litres of carbon monoxide (CO) measured at 68° F.

6. 38 litres of carbon monoxide at 18° C. and 672 m.m. are required, how much dry hydrogen oxalate must be used?

$$C_2H_2O_4 = H_2O + CO_2 + CO.$$

7. 10 litres of carbon monoxide at 14° C. and 760 m.m. are required, what volume of normal carbon dioxide must be passed over red-hot carbon, and what mass of carbon is absorbed?

$$CO_2 + C = 2CO.$$

8. What volume is occupied by 100 grams of (α) carbon monoxide CO? (β) carbon dioxide CO_2?

9. 30 c.c. of carbon monoxide are exploded with excess of oxygen, 35 c.c. of gas remain, what volume of oxygen was added?

$$CO + O = CO_2.$$

10. 50 c.c. of a mixture of carbon monoxide and hydrogen are exploded with excess of oxygen. 30 c.c. of gas remain, of which 20 c.c. are absorbed by potassium hydrate. What was the volume of the carbon monoxide and of the added oxygen?

$$CO + O = CO_2.$$
$$H_2 + O = H_2O.$$

11. Find the mass of 10 litres of carbon monoxide (CO) measured at 39° C. and 800 m.m.

12. A substance contains carbon 20 per cent., oxygen 26·6 per cent. and sulphur 53·3 per cent. Find its formula.

13. A diamond weighing 7 grams is burnt in oxygen, what volume of carbon dioxide is formed?

$$C + O_2 = CO_2.$$

14. 10 grams of turpentine are burnt, what volume of carbon dioxide is formed?

$$C_{10}H_{16} + 28O = 8H_2O + 10CO_2.$$

15. 10 grams of common alcohol are burnt, what volume of carbon dioxide is formed?

$$C_2H_6O + 6O = 3H_2O + 2CO_2.$$

16. 10 lbs. of paraffin candles are burnt, what mass of carbon dioxide and of water is formed?

$$C_{20}H_{42} + 61O = 20CO_2 + 21H_2O.$$

17. 8·96 litres of carbon dioxide at 31° C. and 912 m.m. are required, how much marble must be used?

$$CaCO_3 + 2HCl = CaCl_2 + H_2O + CO_2.$$

18. 200 grams of platinum (sp. ht. ·032) are cooled in solid carbon dioxide and then dropped into 100 grams of water at 16°C. If the temperature of the water fall to 10° C., what is the temperature of the carbon dioxide?

19. How much marble must be dissolved in acid to give 20 litres of carbon dioxide at 18° C. and 740 m.m.?

$$CaCO_3 + 2HCl = CaCl_2 + H_2O + CO_2.$$

20. How much potassium and hydrogen carbonate is required to give a litre of carbon dioxide?

$$KHCO_3 + HCl = KCl + H_2O + CO_2.$$

21. At Paris in 1840 the daily production of carbon dioxide (CO_2) was 3 000 000 cubic metres. Find the mass of the gas.

22. 4 kilograms of carbon are burnt in an engine, which can apply 12 per cent. of the theoretical energy to external work. Through how many metres would the force suffice to lift 1000 kilograms?

23. 1000 volumes of water form 1092 volumes of ice. To what temperature Centigrade must 1000 volumes of mercury at 0° C. be heated to expand half as much? How much carbon must be burnt to heat the mercury, if volumes be reckoned in cubic inches? And also how much to melt the ice? (Latent heat of water 80. Sp. ht. of mercury ·033. Coeff. of expansion of mercury for 1° C. $\frac{1}{5550}$).

24. How many ounces avoirdupois of sodium and hydrogen carbonate and of hydrogen tartrate must be used to charge a gasogen holding 4 litres with gas under a pressure

of 4 atmospheres? (1 volume of water at 10° C. absorbs 1·1847 volumes of carbon dioxide under 1 atmosphere).

$$HNaCO_3 + C_4H_6O_6 = C_4H_5NaO_6 + H_2O + CO_2.$$

25. Calcium hydrate is soluble in 730 times its mass of water, what volume of carbon dioxide at 13° C. is required to precipitate all the calcium from 3000 grams of lime-water?

$$CaH_2O_2 + CO_2 = H_2O + CaCO_3.$$

26. How many grams do 10 litres of marsh-gas (CH_4) weigh?

27. 10 grams of hexane are burnt, what volume of carbon dioxide is formed?

$$C_6H_{14} + 19O = 7H_2O + 6CO_2.$$

28. What is the percentage composition of (α) marsh-gas CH_4? (β) ethene C_2H_4? (γ) ethine C_2H_2?

29. 15·2 litres of methane at 17° C. and 870 m.m. are required, how much sodium acetate must be used?

$$2NaC_2H_3O_2 + BaH_2O_2 = BaCO_3 + Na_2CO_3 + 2CH_4.$$

30. 374·166 c.c. of hydrogen diffuse through a certain apparatus in 10 seconds, what volume of ethene (C_2H_4) will diffuse under the same circumstances?

31. 25 c.c. of ethene are exploded with 100 c.c. of oxygen, what volume of carbon dioxide is formed, and what volume of oxygen is left?

$$C_2H_4 + 3O_2 = 2CO_2 + 2H_2O.$$

32. Find the mass of a litre of (α) ethine C_2H_2, (β) ethene C_2H_4.

33. What is the percentage composition of potassium cyanide KCN?

34. Find the mass of 20 litres of cyanogen (C_2N_2).

35. 145 grams of potassium ferrocyanide were dissolved in 400 c.c. of water, and the density of the solution was found to be 1·16. By how much did the solution of the ferrocyanide increase the volume of the liquid?

36. Find the mass of 76 litres of marsh-gas (CH_4) measured at 31° C.

37. Find the mass of 1·51 litres of benzene (C_6H_6) vapour measured at 180° C.

38. What is the mass of 3·73 litres of ethene (C_2H_4) measured at 100° C?

39. What volume of ethene at 16° C. and 750 m.m. is required to saturate 100 c.c. of bromine (Δ 3)?

$$C_2H_4 + Br_2 = C_2H_4Br_2.$$

40. Find the percentage of water in crystallized hydrogen oxalate ($C_2H_2O_4 . 2H_2O$).

41. 100 grams of crystallized hydrogen oxalate are heated with hydrogen sulphate, what volume of carbon monoxide at 30° C. and 747 m.m. is evolved?

$$C_2H_2O_4 . 2H_2O = 3H_2O + CO_2 + CO.$$

42. 100 litres of carbon monoxide at 14° C. and 1000 m.m. are required, how much sodium formate must be heated with hydrogen sulphate?

$$NaCHO_2 + H_2SO_4 = NaHSO_4 + H_2O + CO.$$

43. The vapour-density of phenyl-naphthalene ($C_{16}H_{12}$) was determined by Meyer's third method. 0·1105 gram gave 13·2 c.c. of nitrogen at 17·5° C. The barometer stood at 754·1 m.m., and the tension of the aqueous vapour was 14·9 m.m. Find the density of the vapour.

44. A substance contains carbon 53·16 per cent., hydrogen 6·3 per cent., and oxygen 40·54 per cent. Find its formula.

45. The vapour density of dibromamylene ($C_5H_{10}Br_2$) was determined by Meyer's third method. 0·12 gram gave 13·1 c.c. of air at 17°C. The barometer stood at 758 m.m., and the tension of aqueous vapour was 14·4 m.m. Find the density of the vapour.

46. A globe, the capacity of which was 178 c.c., when filled with air at 15° C. weighed 23·45 grams, and when filled with the vapour of a hydrocarbon at 110° C. weighed 23·72 grams. Find the density of the vapour.

47. Camphor vapour is 5·312 times as heavy as air, what is its double density referred to hydrogen?

48. Find the mass of 295 c.c. of camphor ($C_{10}H_{16}O$) vapour at 210° C.

49. A globe, the volume of which was 810 c.c. when full of air at 14° C. weighed 119 grams, and when full of alcohol vapour at 100° C. weighed 119·2 grams. Find the density of the vapour.

50. A substance contains carbon 45 parts, hydrogen 7·5 parts, and oxygen 60 parts. Find its most simple formula.

51. 0·25 gram of an organic substance gave when burnt 0·8103 gram of carbon dioxide and 0·2655 gram of water. Its vapour is 4·76 times heavier than air. Find its formula.

52. 0·243 gram of a substance, containing only carbon, hydrogen and oxygen, gave 0·693 gram of carbon dioxide and 0·162 gram of water. Find its simplest formula.

53. Find the formula of a substance containing carbon 26·66 per cent., oxygen 53·33 per cent., and water 20 per cent.

54. A neutral substance was found to contain carbon 39·56 per cent., hydrogen 7·69 per cent., and oxygen 52·75 per cent. Find its formula.

55. 0·3807 gram of an organic acid gave 0·9575 gram of carbon dioxide and 0·1698 gram of water. 0·4287 gram of the silver salt gave 0·202 gram of silver. Find the formula of the acid.

56. A body contains carbon 50·37 per cent., hydrogen 6·33 per cent., nitrogen 17·95 per cent., and oxygen 25·36 per cent. Find its formula.

57. A substance contains carbon 49·485 per cent., hydrogen 5·155 per cent., nitrogen 28·866 per cent., and oxygen 16·495 per cent. Find its formula.

58. A substance contains carbon 35·71 per cent., hydrogen 2·38 per cent., nitrogen 33·33 per cent., and oxygen 28·58 per cent. Find its formula.

59. 4·85 grams of an organic substance gave when burnt 6·95 grams of carbon dioxide and 0·95 gram of water. 5·46 grams of it gave 681 c.c. of nitrogen at 13° C. and 775 m.m. Calculate its percentage composition and formula.

60. A substance contains carbon 68·67 per cent., hydrogen 4·95 per cent., and oxygen 26·38 per cent., and its vapour is 4·226 times heavier than air. Find its formula.

61. A body contains carbon 19·04 per cent., hydrogen 4·76 per cent., sulphur 25·4 per cent., and oxygen 50·8 per cent. Find its formula.

62. A substance contains carbon 74·07 per cent., hydrogen 8·64 per cent., and nitrogen 17·29 per cent. Find its formula.

63. 0·4102 gram of a liquid gave when burnt with lead chromate 0·5119 gram of carbon dioxide, and 0·2286 gram of water. 0·3878 gram of it gave 0·3975 gram of silver iodide and 0·0148 gram of silver. Calculate its percentage composition and formula.

CHAPTER XI.

CHLORINE. $Cl = 35{\cdot}5$.

1. WHAT volume is occupied by 177·5 grams of chlorine (Cl_2)?

2. How much salt is required to make 28 litres of chlorine?

$$2NaCl + MnO_2 + 2H_2SO_4 = 2H_2O + Na_2SO_4 + MnSO_4 + Cl_2.$$

3. What volume of chlorine can be made from 2078 grams of salt?

$$2NaCl + MnO_2 + 2H_2SO_4 = 2H_2O + Na_2SO_4 + MnSO_4 + Cl_2.$$

4. How many grams of manganese dioxide are required to make 40 litres of chlorine at 37° C.?

$$MnO_2 + 4HCl = 2H_2O + MnCl_2 + Cl_2.$$

5. How much common salt must be used to make 150 c.c. of gaseous hydrogen chloride?

$$2NaCl + H_2SO_4 = Na_2SO_4 + 2HCl.$$

6. How many pounds of common salt are required to make 150 pounds of solution of hydrogen chloride containing 31·5 per cent. of real acid?

$$2NaCl + H_2SO_4 = Na_2SO_4 + 2HCl.$$

7. What volume of chlorine at 39° C. is required to make 1000 grams of bleaching powder?

$$Cl_2 + CaH_2O_2 = H_2O + CaOCl_2.$$

8. How many grams of hydrogen chloride can be obtained from 100 grams of salt?

$$2NaCl + H_2SO_4 = Na_2SO_4 + 2HCl.$$

9. How much salt is required to make 1000 grams of hydrogen chloride?

$$2NaCl + H_2SO_4 = Na_2SO_4 + 2HCl.$$

10. 20 grams of dilute hydrogen chloride gave 4·53 grams of silver chloride, what is the percentage of real acid in the solution?

$$HCl + AgNO_3 = HNO_3 + AgCl.$$

11. What volume of hydrogen is required to unite with one gram of chlorine?

$$H + Cl = HCl.$$

12. What volume is occupied by 78 grams of gaseous hydrogen chloride (HCl)?

13. 500 grams of potassium chlorate are heated, how much potassium chloride is left?

$$KClO_3 = KCl + 3O.$$

14. 490 grams of potassium chlorate are heated, what volume of oxygen is evolved?

$$KClO_3 = KCl + 3O.$$

15. What volume of oxygen at 17° C. is evolved on heating 245 grams of potassium chlorate?

$$KClO_3 = KCl + 3O.$$

16. What volume of oxygen and mass of potassium perchlorate is formed on gently heating 245·2 grams of potassium chlorate?

$$2KClO_3 = KCl + KClO_4 + O_2.$$

17. How many litres of chlorine at 13° C. and 720 m.m. are required to produce 3810 grams of bleaching powder?

$$Cl_2 + CaH_2O_2 = H_2O + CaOCl_2.$$

18. How many kilograms of pyrolusite, containing 80 per cent. of manganese dioxide, are required to decompose 400 kilograms of hydrogen chloride, containing $\frac{1}{3}$ of its mass of real acid?

$$MnO_2 + 4HCl = 2H_2O + MnCl_2 + Cl_2.$$

19. 100 grams of sodium chloride are heated with hydrogen sulphate, what volume of hydrogen chloride at 39° C. is evolved?

$$2NaCl + H_2SO_4 = Na_2SO_4 + 2HCl.$$

20. Find the percentage composition of bleaching powder if its formula be (α) CaO_2Cl_2, (β) $CaOCl_2$, (γ) $Ca_3H_6O_6Cl_4$.

21. The density of chlorine trioxide is found to be 39·7, and that of the tetroxide 33·8; what might these numbers be expected to be?

22. How much potassium chlorate is required to make 36·48 litres of oxygen at 15° C. and 750 m.m.?

$$KClO_3 = KCl + 3O.$$

23. Find the mass of one litre of chloroform ($CHCl_3$) vapour measured at 200° C.

24. Find the mass of 1·6 litres of carbonyl chloride ($COCl_2$) measured at 26° C. and 730 m.m.

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25. What volume of chlorine at 12° C. and 750 m.m. can be obtained from 1170 grams of salt?

$$2NaCl + MnO_2 + 2H_2SO_4 = 2H_2O + Na_2SO_4 + MnSO_4 + Cl_2.$$

26. 10 grams of potassium dichromate are heated with hydrogen chloride, what volume of chlorine at 30° C. and 740 m.m. is given off?

$$K_2Cr_2O_7 + 14HCl = 7H_2O + 2KCl + Cr_2Cl_6 + 3Cl_2.$$

27. 463 grams of common salt are heated with hydrogen sulphate, what volume of hydrogen chloride is given off?

$$2NaCl + H_2SO_4 = Na_2SO_4 + 2HCl.$$

28. What volume of chlorine will diffuse under the same circumstances as 10 litres of nitrogen?

29. What volume of chlorine at 20° C. is required to convert 10 grams of copper leaf into cupric chloride?

$$Cu + Cl_2 = CuCl_2.$$

30. 5 grams of silver chloride are heated in hydrogen, what volume of hydrogen chloride is formed?

$$AgCl + H = Ag + HCl.$$

31. From 2078 grams of sodium chloride what volume of chlorine can be obtained?

$$2NaCl + MnO_2 + 2H_2SO_4 = 2H_2O + Na_2SO_4 + MnSO_4 + Cl_2.$$

32. One gram of silver oxide is thrown into hydrogen hypochlorite, what volume of oxygen at 21° C. and 770 m.m. is given off?

$$Ag_2O + 2HClO = 2AgCl + H_2O + O_2.$$

33. 8·5 c.c. of the strongest solution of hydrogen chloride (containing 500 times its volume of the normal gas) is warmed with twice its volume of hydrogen sulphate. What volume of hydrogen chloride at 20° C. and 780 m.m. is given off?

34. A solution of 10 grams of bleaching powder is run into excess of hot hydrogen chloride, what volume of chlorine at 13° C. is given off?

$$CaOCl_2 + 2HCl = CaCl_2 + H_2O + Cl_2.$$

35. A gram of bleaching powder when boiled with cupric oxide gave 80 c.c. of oxygen at 7° C. and 800 m.m. Find the percentage of real bleaching powder in the sample.

$$CaOCl_2 = CaCl_2 + O.$$

36. When 1·205 grams of bleaching powder were boiled with cupric oxide, 58·5 c.c. of oxygen at 13·5° C. measured over water were obtained. The height of the water column was 340 m.m. and of the barometer 766 m.m. Find the percentage of real bleaching powder in the sample.

$$CaOCl_2 = CaCl_2 + O.$$

37. 50 c.c. of chloroform (Δ1·5) are run into a hot mixture of potassium dichromate and hydrogen sulphate; what volume of carbonyl chloride at 10° C. and 730 m.m. is evolved?

$$2CHCl_3 + 3O = H_2O + Cl_2 + 2COCl_2.$$

38. 10 litres of chlorine at 15° C. are passed into a warm mixture of carbon disulphide and antimony pentachloride, how much carbon tetrachloride is formed?

$$4Cl_2 + CS_2 = 2SCl_2 + 2CCl_4.$$

CHAPTER XII.

BROMINE. Br = 80.

1. **SEA-WATER** contains 0·007 per cent. of magnesium bromide ($MgBr_2$). What volume of it is required to obtain one litre of bromine ($\Delta 3$)?

2. What is the volume of 1000 grams of bromine $\Delta 3$?

3. Find the mass of 1 c.c. of bromine vapour (Br_2).

4. If the mercury ($\Delta 13{\cdot}5$) barometer stands at 80 c.m.; how high will one of bromine ($\Delta 3$) stand?

5. Find the percentage composition of bromine hydrate

$$(Br_2 10H_2O).$$

6. How much potassium bromide is required to prepare 10 grams of bromine?

$$2KBr + MnO_2 + 2H_2SO_4 = 2H_2O + K_2SO_4 + MnSO_4 + Br_2.$$

7. How many grams of bromine are there in a litre of gaseous hydrogen bromide (HBr)?

8. How much potassium (α) bromide, (β) bromate is formed on adding 520 grams of bromine to a solution of potassium hydrate?

$$6Br + 6HKO = 3H_2O + 5KBr + KBrO_3.$$

9. Find the mass of 127 c.c. of gaseous hydrogen bromide (HBr).

10. 9 grams of potassium bromide are distilled with hydrogen phosphate, what volume of gaseous hydrogen bromide at 26° C. is evolved?

$$KBr + H_3PO_4 = KH_2PO_4 + HBr.$$

11. 70 grams of bromine are dissolved in water, what volume of hydrogen sulphide at 15° C. is required to convert them into hydrogen bromide?

$$Br_2 + H_2S = S + 2HBr.$$

12. The strongest solution of hydrogen bromide (HBr Δ1·515) contains half its mass of real acid, how much bromine is there in a litre of the solution?

13. Find the percentage composition of silver bromide (AgBr).

14. 10 grams of potassium bromate are heated, what volume of oxygen at 13° C is given off?

$$KBrO_3 = KBr + 3O.$$

15. Hydrogen bromide is 2·71 times as heavy as air, find its molecular weight.

16. 100 grams of water dissolve 3 grams of bromine, if the vapour of the solution be passed through a red-hot tube, what volume of oxygen at 13° C. is set free?

$$Br_2 + H_2O = 2HBr + O.$$

17. Find the mass of 1 c.c. of bromine (Br_2) vapour measured at 150° C.

18. 10 grams of phosphorus tribromide are decomposed by water and silver nitrate is added, how much silver bromide precipitates?

$$PBr_3 + 3H_2O + 3AgNO_3 = H_3PO_3 + 3HNO_3 + 3AgBr.$$

19. How much phosphorus, and what volume of bromine (Δ 3) are required to make 10 litres of hydrogen bromide?

$$P + 3Br + 3H_2O = H_3PO_3 + 3HBr.$$

20. De Marignac found that 3·946 grams of silver dissolved in hydrogen nitrate were precipitated by 4·353 grams of potassium bromide. Calculate the atomic weight of bromine.

$$AgNO_3 + KBr = KNO_3 + AgBr.$$

21. A spherical glass bulb is to contain 10 grams of bromine (Δ 3), what must its internal radius be?

CHAPTER XIII.

IODINE. $I = 127$.

1. How much ferric chloride is required to obtain the iodine from 100 tonnes of kelp, each tonne of which contains 4·07 kilograms of iodine?

$$2NaI + Fe_2Cl_6 = 2NaCl + 2FeCl_2 + I_2.$$

2. How many times is solid iodine (Δ 4·94) heavier than an equal volume of its vapour measured at 350° C.?

3. Iodine vapour is 8·716 times as heavy as air, find its molecular weight.

4. 3·81 grams of iodine vapour mixed with hydrogen are passed through a red-hot tube, what volume of hydrogen iodide is formed?

$$H + I = HI.$$

5. What mass of hydrogen is there in 1 litre of hydrogen (*a*) bromide (HBr) and (*β*) iodide (HI)?

6. 20 grams of iodine are suspended in water, what volume of hydrogen sulphide at 15° C. is required to convert them into hydrogen iodide?

$$I_2 + H_2S = S + 2HI.$$

7. How much iodine is there in a litre of a solution (Δ 1·7) containing 52 per cent. of hydrogen iodide (HI)?

8. How much iodine, phosphorus, and potassium iodide must be used to make 10 litres of gaseous hydrogen iodide at 15° C.?

$$10I_2 + 4P + 8KI + 16H_2O = 4K_2HPO_4 + 28HI.$$

9. Find the percentage of iodine and of oxygen in iodine (α) pentoxide (I_2O_5) and (β) septoxide (I_2O_7).

10. Find the percentage composition of hydrogen (α) iodate (HIO_3) and (β) periodate (HIO_4).

11. 119 grams of iodine are suspended in water, what volume of chlorine is required to convert them into hydrogen iodate?

$$I + 5Cl + 3H_2O = 5HCl + HIO_3.$$

12. 14 grams of potassium iodate are heated, what volume of oxygen at 13° C. is evolved?

$$KIO_3 = KI + 3O.$$

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13. How much phosphorus and iodine must be used to make 100 litres of hydrogen iodide at 30° C. and 740 m.m.?

$$P + 3I + 3H_2O = H_3PO_3 + 3HI.$$

14. A balloon contains 5 litres of chlorine at 20° C. and 780 m.m., how much iodine must be thrown into it to obtain the monochloride?

$$I + Cl = ICl.$$

15. 0·1 gram of potassium dichromate is distilled with hydrogen chloride, how much iodine will the resulting chlorine set free from potassium iodide?

$$K_2Cr_2O_7 + 14HCl = 7H_2O + 2KCl + Cr_2Cl_6 + 6Cl.$$
$$KI + Cl = KCl + I.$$

16. A mixture of potassium chloride, bromide, and iodide was precipitated by silver nitrate and the silver chloride bromide and iodide was found to weigh 15·57 grams; after heating with bromine water, the silver chloride and bromide weighed 14·69 grams; lastly after heating with chlorine water the precipitate weighed 12·2 grams. Find how much chlorine, bromine, and iodine was present in the mixture.

17. Find the percentage composition of iodoform (CHI_3).

CHAPTER XIV.

FLUORINE. $F = 19$.

1. WHAT mass of hydrogen fluoride can be obtained from 100 grams of fluor-spar?

$$CaF_2 + H_2SO_4 = CaSO_4 + 2HF.$$

2. 100 grams of fluor-spar are heated with hydrogen sulphate, how much calcium sulphate is formed?

$$CaF_2 + H_2SO_4 = CaSO_4 + 2HF.$$

3. What volume of hydrogen fluoride at 15° C. can be obtained from 7·8 grams of fluor-spar?

$$CaF_2 + H_2SO_4 = CaSO_4 + 2HF.$$

4. 468 grams of fluor-spar are heated with silicon dioxide and hydrogen sulphate. If the gas produced be passed into water, how much silicon dioxide and hydrogen fluosilicate is formed?

$$2CaF_2 + SiO_2 + 2H_2SO_4 = 2CaSO_4 + 2H_2O + SiF_4.$$
$$3SiF_4 + 2H_2O = SiO_2 + 2H_2SiF_6.$$

5. 100 grams of fluor-spar gave, when heated with hydrogen sulphate, 174·5 grams of calcium sulphate. What is the atomic weight of fluorine?

$$CaF_2 + H_2SO_4 = CaSO_4 + 2HF.$$

6. Find the percentage composition of (α) fluor-spar (CaF_2), (β) cryolite ($Na_6Al_2F_{12}$).

7. 3·2617 grams of calcium fluoride gave 5·6867 grams of calcium sulphate. Find the atomic weight of fluorine.

$$CaF_2 + H_2SO_4 = CaSO_4 + 2HF.$$

8. What volume of hydrogen fluoride at 20° C. can be obtained from 20 grams of cryolite?

$$Na_6Al_2F_{12} + 6H_2SO_4 = 3Na_2SO_4 + Al_23SO_4 + 12HF.$$

9. What volume of hydrogen fluoride can be obtained from 50 grams of fluor-spar?

$$CaF_2 + H_2SO_4 = CaSO_4 + 2HF.$$

10. 150 c.c. of hydrogen fluoride are passed over heated sodium, how much sodium fluoride is formed?

$$HF + Na = H + NaF.$$

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11. Find the mass of 10 litres of hydrogen fluoride (HF) at 30° C. and 740 m.m.

12. Commercial hydrogen fluoride contains 35 per cent. of real acid, if 100 grams of it be heated with excess of hydrogen sulphate, what volume of gas (HF) at 20° C. and 750 m.m. is evolved?

13. To determine the density of hydrogen fluoride, a balloon holding 4394·7 c.c. was filled with the vapour at 30° C. and 745 m.m. The following results were obtained:—

Mass of the balloon and vapour	428·255 grams.
Mass of the empty balloon	421·436 grams.

Find the density of hydrogen fluoride.

14. What difference does the result obtained in 13 make in the answers of 11 and 12?

CHAPTER XV.

SULPHUR. $S = 32$.

1. FIND the percentage composition of (α) galena (PbS), (β) zinc blende (ZnS).

2. Find the formulæ of substances containing (α) copper 34·5 per cent., iron 30·5 per cent., and sulphur 35 per cent., (β) calcium 29·4 per cent., sulphur 23·6 per cent., and oxygen 47 per cent.

3. What volume is occupied by 1000 kilograms of (α) common sulphur (Δ 2·05), and (β) plastic sulphur (Δ 1·957)?

4. 8 grams of sulphur are burnt in air, what volume of sulphur dioxide is formed?

$$S + O_2 = SO_2.$$

5. 20 grams of sulphur are burnt in oxygen, what volume of sulphur dioxide is formed?

$$S + O_2 = SO_2.$$

6. 9·6 grams of sulphur are heated in hydrogen, what volume of hydrogen sulphide is formed?

$$S + H_2 = H_2S.$$

7. What volume is occupied by 19·2 grams of sulphur dioxide (SO_2)?

8. How much sulphur must be burnt to make 10 litres of sulphur dioxide?

$$S + O_2 = SO_2.$$

9. What mass of hydrogen sulphate (Δ 1·84) will a tank 1 by 2 by 3 metres hold?

10. 102·4 grams of sulphur will form how much hydrogen sulphate?

$$S + 3O + H_2O = H_2SO_4.$$

11. Find the percentage composition of hydrogen (α) sulphite (H_2SO_3), and (β) sulphate (H_2SO_4).

12. A tank of hydrogen sulphate (Δ 1·84) is 10 feet long and 5 feet wide and deep. How many tonnes of acid will it hold?

13. 16 litres of hydrogen diffuse through an apparatus in 100 minutes, how much sulphur dioxide (SO_2) will diffuse under the same conditions?

14. What volume of sulphur dioxide at 20° C. and 740 m.m. can be obtained by the action of 20 grams of hydrogen sulphate upon copper?

$$Cu + 2H_2SO_4 = CuSO_4 + 2H_2O + SO_2.$$

15. 50 c.c. of sulphur (Δ 2) are burnt, what volume of sulphur dioxide at 14° C. and 780 m.m. is formed?

$$S + O_2 = SO_2.$$

16. How much sulphur is there in a litre of sulphur dioxide (SO_2) measured at 39° C. and 720 m.m.?

17. The density of the vapour of hydrogen sulphate referred to air is 1·697. What is its apparent molecular weight?

18. How much copper must be dissolved in hydrogen sulphate to furnish 10 litres of sulphur dioxide at 13° C.?

$$Cu + 2H_2SO_4 = CuSO_4 + 2H_2O + SO_2.$$

19. How much copper and hydrogen sulphate are required to make 1000 grams of sulphur dioxide?

$$Cu + 2H_2SO_4 = CuSO_4 + 2H_2O + SO_2.$$

20. 10 c.c. of sulphur (Δ 2) are burnt, what volume of sulphur dioxide at 30° C. is formed?

$$S + O_2 = SO_2.$$

21. How much copper must be dissolved in hydrogen sulphate to make 10 litres of sulphur dioxide at 18° C.?

$$Cu + 2H_2SO_4 = CuSO_4 + 2H_2O + SO_2.$$

22. What volume is occupied by 100 grams of sulphur-vapour (S_6) at 400° C.?

23. 50 kilograms of alcohol are mixed with 50 kilograms of carbon disulphide and burnt. From how large a room could the oxygen (20 per cent. by volume available) be removed?

$$\begin{aligned} C_2H_6O + 3O_2 &= 3H_2O + 2CO_2, \\ CS_2 + 3O_2 &= \phantom{3H_2O+{}} CO_2 + 2SO_2. \end{aligned}$$

24. 10 c.c. of carbon disulphide CS_2 (Δ 1·27) are heated, what does the gas measure at 350° C. and 600 m.m.?

25. By heating 10000 grains of silver in sulphur-vapour Dumas obtained 11481·5 grains of silver sulphide. Find the atomic weight of sulphur.

$$Ag_2 + S = Ag_2S.$$

26. A litre of sulphur dioxide is found to weigh 2·8672 grams, what is its molecular weight?

27. A body contains hydrogen 1·12 per cent., sulphur 35·9 per cent., and oxygen 62·98 per cent. Find its formula and name.

28. What volume is occupied by 225 grams of hydrogen sulphide (H_2S) at 273° C.?

29. How much hydrogen sulphate can be made from a ton of iron pyrites?

$$2FeS_2 + 4H_2O + 15O = Fe_2O_3 + 4H_2SO_4.$$

30. Find the mass in grams of a cubic inch of hydrogen sulphate (Δ 1·84).

31. How many tons of pyrites containing 42 per cent. of sulphur are required to make 100 tons of oil of vitriol containing 70 per cent of real acid?

$$S + 3O + H_2O = H_2SO_4.$$

32. 100 grams of lead form 146·45 grams of lead sulphate, find the molecular weight of hydrogen sulphate.

$$Pb + H_2SO_4 = H_2 + PbSO_4.$$

33. How much oil of vitriol containing 70 per cent. of real acid can be made from 250 kilos. of pyrites containing 42 per cent. of sulphur?

$$S + 3O + H_2O = H_2SO_4.$$

34. What volume of hydrogen sulphate (Δ 1·84) can be obtained from 1000 kilos. of iron pyrites?

$$2FeS_2 + 4H_2O + 15O = Fe_2O_3 + 4H_2SO_4.$$

35. How much sulphur is there in a litre of hydrogen sulphate (H_2SO_4 Δ 1·84)?

36. 10 grams of hydrogen sulphate are heated with phosphorus pentachloride, what volume will the sulphuryl dichloride formed occupy at 350° C?

$$H_2SO_4 + 2PCl_5 = 2POCl_3 + 2HCl + SO_2Cl_2.$$

37. 5 c.c. of dilute hydrogen sulphate are naturalized by 18·8 c.c. of a solution of sodium carbonate, containing 106 grams of the salt per litre. How many grams of hydrogen sulphate are there in a litre of the dilute acid?

$$Na_2CO_3 + H_2SO_4 = CO_2 + H_2O + Na_2SO_4.$$

38. 4 litres of sulphur dioxide at 13° C. are mixed with oxygen and passed over a heated mixture of cupric and chromic oxides, how much sulphur trioxide is formed?

$$SO_2 + O = SO_3.$$

39. Find the percentage composition of (α) potassium sulphate (K_2SO_4), and (β) sodium sulphate (Na_2SO_4).

40. Find the percentage composition of crystallized ferrous sulphate ($FeSO_4 . 7H_2O$), and common alum ($K_2Al_24SO_4 . 24H_2O$).

41. To make 100 litres of hydrogen sulphide, how much ferrous sulphide must be dissolved in acid?

$$FeS + 2HCl = FeCl_2 + H_2S.$$

42. What volume of hydrogen sulphide will diffuse under the same circumstances as 10 litres of oxygen?

43. Two litres of hydrogen sulphide and one litre of sulphur dioxide both at 0° C. are passed through a red-hot tube, what volumes of sulphur and steam at 1000° C. are formed?

$$2H_2S + SO_2 = 3S + 2H_2O.$$

44. 20 grams of sulphur are heated in hydrogen, what volume of hydrogen sulphide at 300° C. is formed?

$$S + H_2 = H_2S.$$

45. What volume of air is required to burn one litre of hydrogen sulphide?

$$H_2S + 3O = H_2O + SO_2.$$

46. 10 grams of ferrous sulphide are dissolved in acid, what volume of hydrogen sulphide is evolved?

$$FeS + H_2SO_4 = FeSO_4 + H_2S.$$

47. 390 grams of antimony sulphide are dissolved in hot hydrogen chloride, what volume of hydrogen sulphide at 30° C. is given off?

$$Sb_2S_3 + 6HCl = 2SbCl_3 + 3H_2S.$$

48. How many grams of sulphur are there in 600 c.c. of hydrogen sulphide (H_2S)?

49. Find the mass of a roll of brimstone (Δ 2) 1 m. long and 4 cm. in diameter.

50. 10 grams of carbon disulphide (CS_2) vapour occupy what volume at 210° C.?

51. Find the percentage composition of sodium thiosulphate ($Na_2S_2O_3 . 5H_2O$).

52. What volume of chlorine at 15° C. and 720 m.m. must be passed into excess of melted sulphur to make 245 grams of sulphur monochloride?

$$Cl_2 + S_2 = S_2Cl_2.$$

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53. What volume of air is required to burn 1000 grams of sulphur?

$$S + O_2 = SO_2.$$

54. 2·867 grams of sulphur are burnt, what volume of sulphur dioxide at 30° C. is formed?

$$S + O_2 = SO_2.$$

55. What is the density of hydrogen sulphide (H_2S) referred to air?

56. What is the mass of 4 litres of carbon oxysulphide (COS) at 30° C.?

57. A cubic decimetre of ferrous sulphide (Δ 4·4) is dissolved in dilute acid, what volume of hydrogen sulphide at 17° C. and 770 m.m. is given off?

$$FeS + H_2SO_4 = FeSO_4 + H_2S.$$

58. What volume would the vapour of 10 grams of hydrogen sulphate (H_2SO_4) occupy at 400° C.?

59. What volume of nitric oxide is required to burn 10 grams of carbon disulphide?

$$CS_2 + 6NO = 6N + CO_2 + 2SO_2.$$

60. If 134 grams of antimony sulphide are dissolved in hot hydrogen chloride, what volume of hydrogen sulphide at 15° C. is given off?

$$Sb_2S_3 + 6HCl = 2SbCl_3 + 3H_2S.$$

61. A room 5 by 4 by 5 metres, the air of which contains 20 per cent. by volume of available oxygen, is to be disinfected. What volume of carbon disulphide (Δ 1·2) can be burnt in it?

$$CS_2 + 3O_2 = CO_2 + 2SO_2.$$

62. What volume of carbon disulphide (Δ 1·27) must be burnt to give 10 litres of sulphur dioxide at 15° C., and 750 m.m.?

$$CS_2 + 3O_2 = CO_2 + 2SO_2.$$

63. 100 grams of mercury are heated with hydrogen sulphate, what volume of sulphur dioxide at 30° C. and 800 m.m. is given off?

$$Hg + 2H_2SO_4 = HgSO_4 + 2H_2O + SO_2.$$

64. 10 litres of hydrogen sulphide at 15° C. are passed into antimony trichloride, how much antimony trisulphide precipitates?

$$3H_2S + 2SbCl_3 = 6HCl_3 + Sb_2S_3.$$

65. To make 1000 kilos. of hydrogen sulphate, how much pyrites, what volume of air at 15° C., and what volume of steam at 300° C. is required?

$$2FeS_2 + 4H_2O + 15O = Fe_2O_3 + 4H_2SO_4.$$

CHAPTER XVI.

BORON. $B = 11$.

1. FIND the formulæ of substances containing (α) boron 31·19 per cent., and oxygen 68·81 per cent., (β) silicon $46{\cdot}\dot{6}$ per cent., and oxygen $53{\cdot}\dot{3}$ per cent.

2. Find the percentage composition of borax ($Na_2B_4O_7\ 10H_2O$).

3. Boron trichloride is 4·07 times as heavy as air, what is its molecular weight?

4. What volume of boron trichloride at 210° C. can be made from 390 grams of boron trioxide?

$$B_2O_3 + 6Cl + 3C = 3CO + 2BCl_3.$$

5. What volume of nitrogen at 15° C. is required to convert 4·4 grams of boron into boron nitride?

$$B + N = BN.$$

6. 7 grams of boron nitride are heated in a current of steam, what volume of ammonia at 13° C. is given off?

$$2BN + 3H_2O = B_2O_3 + 2NH_3.$$

7. 10 grams of boron sulphide are heated in steam, what volume of hydrogen sulphide at 21° C. is formed?

$$B_2S_3 + 3H_2O = B_2O_3 + 3H_2S.$$

8. Crystallized hydrogen borate when heated to 100° C. loses 21·8 per cent. of water, and when heated to 160° C. loses 14·5 per cent. in addition. Find the formulæ of the bodies formed.

$$(B_2O_3)_n(H_2O)_{2n} = (B_2O_3)_n(H_2O)_{3n-x} + (H_2O)_x.$$

9. Find the percentage composition of boron and nitryl chloride ($BNOCl_4$).

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10. 90 grams of fluorspar are heated with boron trioxide and hydrogen sulphate, what volume of boron trifluoride at 15° C. is formed?

$$3CaF_2 + B_2O_3 + 3H_2SO_4 = 3CaSO_4 + 3H_2O + 2BF_3.$$

11. How much does a litre of boron fluoride (BF_3) measured at 50° C., and 1000 m.m. weigh?

12. A substance contains nitrogen 14·68 per cent., hydrogen 3·15 per cent., boron 7·69 per cent., and chlorine 74·47 per cent., find its formula.

13. What volume of ammonia gas at 10° C. is required to convert 10 grams of boron into the nitride?

$$2B + 2NH_3 = 3H_2 + 2BN.$$

CHAPTER XVII.

SILICON. Si = 28.

1. How much silicon can be obtained from 119 grams of potassium silicofluoride?

$$K_2SiF_6 + 4K = 6KF + Si.$$

2. Find the percentage composition of barium silicofluoride $BaSiF_6$.

3. Two litres of the vapour of silicon chloride at 117° C. are passed over heated sodium, how much silicon is formed?

$$SiCl_4 + 4Na = 4NaCl + Si.$$

4. Find the percentage composition of Willemite Zn_2SiO_4.

5. Ten grams of silica are heated with fluor-spar and hydrogen sulphate, what volume of silicon fluoride at 13° C. is formed?

$$SiO_2 + 2CaF_2 + 2H_2SO_4 = 2CaSO_4 + 2H_2O + SiF_4.$$

6. What does a litre of hydrogen silicide (SiH_4) at 13° C. weigh?

7. What volume of chlorine at 26° C. is required to make 100 grams of silicon tetrachloride?

$$SiO_2 + 2C + 4Cl = 2CO + SiCl_4.$$

8. 710 grams of chlorine are passed over a heated mixture of carbon and silicon dioxide. What volume of carbon monoxide and mass of silicon tetrachloride is formed?

$$4Cl + SiO_2 + 2C = 2CO + SiCl_4.$$

9. 20 grams of silica are heated in the vapour of carbon disulphide, how much silicon sulphide and what volume of carbon dioxide at 13° C. is formed?

$$SiO_2 + CS_2 = CO_2 + SiS_2.$$

10. Find the mass of 1·5 litres of the vapour of silicon bromide ($SiBr_4$) measured at 350° C. and 400 m.m.

11. What is the percentage composition of steatite $Mg_3Si_4O_{11} . H_2O$?

12. Find the formula of a substance which contains silicon 26·27 per cent., calcium 18·43 per cent., magnesium 11·06 per cent., oxygen 44·24 per cent.

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13. Find the mass in grams of a sphere of rock-crystal (Δ 2·65), 1 decimetre in diameter.

14. Wollastonite contains silica 51·31 per cent., alumina 1·37 per cent., lime 45·66 per cent., and magnesia 0·73 per cent. Find its formula.

15. Allophane contains silica 23·53 per cent., alumina 37·73 per cent., lime 1·92 per cent., and water 36·86 per cent. Find its formula.

16. Find the volume of 208 grams of silicon fluoride (SiF_4) measured at 60° C.

17. How much silica is formed on burning 2 litres of hydrogen silicide measured at 30° C.?

$$SiH_4 + 4O = SiO_2 + 2H_2O.$$

18. Find the formula of skolezite which contains silica 46·2 per cent., alumina 26·28 per cent., lime 9·22 per cent., sodium oxide 5·16 per cent., and water (low) 13·25 per cent.

19. Sahlite contains silica 54·02 per cent., lime 24·88 per cent., ferrous oxide 8·07 per cent., and magnesia 13·52 per cent. Find its formula.

20. What does one litre of silicon chloroform ($SiHCl_3$) at 180° C. weigh?

21. Silicon chloride vapour is 5·939 times as heavy as air, and silicon fluoride vapour is 3·6 times as heavy as air. Find in each case the double density referred to hydrogen.

22. What volume of chlorine at 10° C. must be used to make 100 grams of silicon tetrachloride?

$$SiO_2 + 2C + 4Cl = 2CO + SiCl_4.$$

23. How much does one litre of silicon tetrachloride ($SiCl_4$) measured at 200° C. weigh?

24. Find the formula of a substance which contains magnesium 22·02 per cent., silicon 25·69 per cent., oxygen 44·04 per cent., and water 8·25 per cent.?

25. Berzelius found topaz to contain alumina 58·38 per cent., silica 34·01 per cent., and fluorine 7·6 per cent. Find its formula.

26. Berzelius found Thomsonite to contain sodium oxide 4·53 per cent., lime 13·54 per cent., alumina 30·7 per cent., silica 38·3 per cent., and water 13 per cent. Find its formula.

27. Bonsdorff found Iolite to contain magnesia 10·45 per cent., ferrous oxide 5 per cent., alumina 32·88 per cent., silica 49·95 per cent., water and loss 1·75 per cent. Find its formula.

28. A specimen of orthoclase was found to contain silica 65·37 per cent., alumina 18·74 per cent., ferric oxide 0·13 per cent., lime 0·27 per cent., potassium oxide 12·98 per cent., and sodium oxide 2·48 per cent. Find the formula.

29. According to Schiel 0·6738 gram of silicon tetrachloride, when decomposed by ammonia, give 2·277 grams of silver chloride. Find the atomic weight of silicon.

$SiCl_4 + 2H_2O + 4NH_3 + 4AgNO_3 = 4AgCl + SiO_2 + 4NH_4NO_3$.

30. Find the percentage composition of triethyl silicoformate $HSiO_3(C_2H_5)_3$.

CHAPTER XVIII.

PHOSPHORUS. $P = 31$.

1. How much phosphorus is there in 9·3 kilograms of calcium phosphate ($Ca_3 2PO_4$)?

2. How much phosphorus is there in 700 grams of bone-ash ($Ca_3 2PO_4$)?

3. How much phosphorus is contained in 120 kilograms of bone-ash containing 85 per cent. of calcium phosphate ($Ca_3 2PO_4$)?

4. The skeleton of a man weighs 24 lbs. and contains 58 per cent. of calcium phosphate ($Ca_3 2PO_4$). Find the quantity of phosphorus present.

5. Find the mass of a round stick of phosphorus (Δ 1·83) 1 decimetre long and 2 centimetres across.

6. 100 litres of yellow (Δ 1·83) are converted into red (Δ 2·14) phosphorus, what is the volume of the latter variety?

7. One gram of phosphorus when burnt gives 2·29 grams of phosphorus pentoxide. Find the atomic weight of phosphorus.

$$P_2 + O_5 = P_2O_5.$$

8. Calculate the mass of 1·234 litres of phosphorus (P_4) vapour.

9. How much phosphorus can be obtained from 169 tons of bones containing 53·7 per cent. of calcium phosphate ($Ca_3 2PO_4$)?

10. Phosphorus vapour is 4·42 times as heavy as air, find its molecular weight.

11. If one gram of phosphorus was found to form 2·903 grams of phosphorus pentoxide, what would the atomic weight of phosphorus be?

$$P_2 + O_5 = P_2O_5.$$

12. How much phosphorus must be burnt to form 46 grams of phosphorus trioxide?

$$P_2 + O_3 = P_2O_3.$$

13. How much phosphorus must be burnt to form 46·86 grams of phosphorus pentoxide?

$$P_2 + O_5 = P_2O_5.$$

14. What volume of air is required to burn 248 grams of phosphorus?

$$P_2 + O_5 = P_2O_5.$$

15. How much bone-ash containing 87 per cent. of calcium phosphate is required to make 200 kilograms of superphosphate of lime?

$$Ca_3 2PO_4 + 2H_2SO_4 = 2CaSO_4 + CaH_4 2PO_4.$$

16. How many kilograms of bone-ash containing 85 per cent. of calcium phosphate are required to make two tons of superphosphate of lime?

$$Ca_3 2PO_4 + 2H_2SO_4 = 2CaSO_4 + CaH_4 2PO_4.$$

17. How much water must be added to 187 grams of phosphorus pentoxide to convert it into hydrogen (*α*) orthophosphate, (*β*) pyrophosphate, and (*γ*) metaphosphate?

$$P_2O_5 + 3H_2O = 2H_3PO_4.$$
$$P_2O_5 + 2H_2O = H_4P_2O_7.$$
$$P_2O_5 + H_2O = 2HPO_3.$$

18. 193 grams of (α) dry (Na_2HPO_4), and (β) crystallized ($Na_2HPO_4 12H_2O$) sodium phosphate are heated; how much sodium pyrophosphate is formed?

$$2Na_2HPO_4 = H_2O + Na_4P_2O_7.$$
$$2Na_2HPO_4 12H_2O = 25H_2O + Na_4P_2O_7.$$

19. How much hydrogen orthophosphate is obtained on heating 1796 grams of phosphorus with hydrogen nitrate?

$$P_2 + 5O + 3H_2O = 2H_3PO_4.$$

20. Calculate the formula of a substance containing calcium 38·72 per cent., phosphorus 20 per cent., and oxygen 41·28 per cent.

21. Calculate the percentage composition of the three silver phosphates (α) Ag_3PO_4, (β) $Ag_4P_2O_7$, (γ) $AgPO_3$.

22. Find the percentage composition of magnesium pyrophosphate ($Mg_2P_2O_7$).

23. Find the percentage composition of crystallized sodium and hydrogen phosphate ($Na_2HPO_4 . 12H_2O$).

24. Find the percentage composition of microcosmic salt ($Na (NH_4) HPO_4 . 4H_2O$).

25. 79 grams of hydrogen phosphite are heated, what volume of phosphine is evolved?

$$4H_3PO_3 = 3H_3PO_4 + H_3P.$$

26. How much sodium hypophosphite can be obtained by boiling 20 grams of phosphorus with sodium hydrate, and what volume of phosphine is given off?

$$P_4 + 3HNaO + 3H_2O = 3NaPH_2O_2 + PH_3.$$

27. How many grams do 10 litres of phosphine (PH_3) weigh?

28. How much phosphorus is contained in 10 litres of phosphine (PH_3) measured at 12° C.?

29. Hydrogen phosphide contains phosphorus 98·41 per cent., and hydrogen 1·59 per cent. Find its simplest formula.

30. 7·26 grams of phosphonium iodide, when heated with potassium hydrate, give one litre of phosphine. Find the atomic weight of phosphorus.

$$PH_3HI + HKO = KI + H_2O + PH_3.$$

31. The vapour of phosphorus oxychloride is 5·3 times as heavy as air, find its molecular weight.

32. What volume of oxygen is required to burn 179 c.c. of phosphine?

$$2PH_3 + 8O = P_2O_5 + 3H_2O.$$

33. Hydrogen phosphide is 1·184 times as heavy as air, find its molecular weight.

34. The vapour of phosphorus trichloride is 4·742 times as heavy as air, find its molecular weight.

35. What volume of chlorine is required to convert 100 grams of phosphorus into the pentachloride?

$$5Cl + P = PCl_5.$$

36. 10 c.c. of phosphorus (Δ 1·77) are dissolved in solution of barium hydrate, what volume of hydrogen phosphide at 21° C. and 531 m.m. is given off?

$$3BaH_2O_2 + 2P_4 + 6H_2O = 3Ba\,(H_2PO_2)_2 + 2H_3P.$$

37. How much do 10 litres of the vapour of phosphorus oxychloride ($POCl_3$) at 300° C. weigh?

38. 10 litres of hydrogen diffuse through a certain apparatus in a certain time, what volume of phosphine (PH_3) will diffuse under similar conditions?

39. 1640 c.c. of phosphine at 15° C. and 297 m.m. occupy what volume at 10° C. and 302 m.m.?

40. How much crystallized hydrogen oxalate must be warmed with 1000 grams of phosphorus pentachloride to convert it into oxychloride?

$$3PCl_5 + C_2H_2O_4 2H_2O = 3POCl_3 + 6HCl + CO + CO_2.$$

41. A substance contains phosphorus 24·61 per cent., oxygen 19·05 per cent., and chlorine 56·37 per cent. Find its formula.

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42. To form 100 grams of hydrogen phosphite, what volume of chlorine at 10° C. must be passed into phosphorus melted under water?

$$3Cl + P + 3H_2O = 3HCl + H_3PO_3.$$

43. 100 grams of lead phosphate are suspended in water, what volume of hydrogen sulphide at 14° C. is required to decompose them?

$$Pb_3 2PO_4 + 3H_2S = 3PbS + 2H_3PO_4.$$

44. What volume of hydrogen sulphide at 30° C. is required to precipitate the lead from 100 grams of lead pyrophosphate?

$$Pb_2P_2O_7 + 2H_2S = 2PbS + H_4P_2O_7.$$

45. 9 grams of phosphorus pentoxide absorbed 2·76 grams of water from the air, find a formula for the body formed?

46. What volume of chlorine at 15° C. must be passed into 100 grams of phosphorus melted under water to convert them into hydrogen phosphite?

$$3Cl + P + 3H_2O = 3HCl + H_3PO_3.$$

47. In making 200 grams of hydrogen phosphite, what volume of hydrogen chloride at 10° C. is evolved?

$$3Cl + P + 3H_2O = 3HCl + H_3PO_3.$$

48. What is the mass of a ball of phosphorus (Δ 1·83) a decimetre in diameter?

49. Find the percentage composition of sodium α-phosphate ($Na_6P_4O_{13}$).

50. Lazulite has the composition phosphorus pentoxide 43·76 per cent., alumina 31·7 per cent., magnesia 10·04 per cent., ferrous oxide 8·17 per cent., and water 5·59 per cent. Find its formula.

51. To form a kilogram of phosphorus pentachloride, what volume of chlorine at 20° C. must be passed into a solution of phosphorus in carbon disulphide?

$$P + Cl_5 = PCl_5.$$

52. How much phosphorus is contained in 4·3 litres of phosphine (PH_3) measured at 22° C. and 730 m.m.?

53. 7·26 grams of phosphonium iodide, when heated with potassium hydrate, give how many litres of phosphine at 30° C.?

$$PH_4I + HKO = KI + H_2O + PH_3.$$

54. What volume of chlorine at 30° C. must be passed into a solution of phosphorus in carbon disulphide to make 476 grams of phosphorus pentachloride?

$$5Cl + P = PCl_5.$$

55. 5 grams of phosphorus are boiled with baryta water, what volume of phosphine at 15° C. is given off?

$$2P_4 + 3BaH_2O_2 + 6H_2O = 3Ba\,(H_2PO_2)_2 + 2PH_3.$$

56. 20 grams of phosphorus pentabromide are boiled with water, what volume of hydrogen bromide at 210° C is given off?

$$PBr_5 + 4H_2O = H_3PO_4 + 5HBr.$$

57. What volume of gaseous chlorine is condensed in 100 grams of (*a*) boron trichloride BCl_3, (β) silicon tetrachloride $SiCl_4$, (γ) phosphorus pentachloride PCl_5?

58. What volume of hydrogen sulphide at 30° C. will react with 100 grams of phosphorus pentachloride?

$$PCl_5 + H_2S = 2HCl + PSCl_3.$$

59. What volume of chlorine at 21° C. must be passed into 100 grams of phosphorus trichloride to convert them into the pentachloride?

$$PCl_3 + 2Cl = PCl_5.$$

60. What volume of vapour at 300° C. and 740 m.m. is formed by 13 grams of phosphorus trichloride (PCl_3)?

61. 100 grams of phosphorus (calorific power 5747) are burnt in oxygen, to what temperature could a kilogram of iron (specific heat 0·1138) be raised from 0° C.?

62. A kilogram of phosphorus in burning evolves 5747 units of heat. To what temperature could 100 kilograms of iron (specific heat 0·112) be raised from 0° C. by burning 2 kilograms of phosphorus?

CHAPTER XIX.

ARSENIC. As = 75.

1. How many grams do two litres of arsenic (As_4) vapour at 327° C. weigh?

2. How much arsenic trioxide is formed by burning 3·567 grams of arsenic in oxygen?

$$As_2 + O_3 = As_2O_3.$$

3. Find the percentage composition of Proustite (Ag_3AsS_3).

4. 878 c.c. of air at 166° C. and 813 m.m. occupy what volume at –41° C. and 696 m.m.?

5. 100 grams of arsenic trioxide are heated with sulphur, what volume of sulphur dioxide and mass of orpiment are formed?

$$2As_2O_3 + 9S = 2As_2S_3 + 3SO_2.$$

6. In a case of poisoning 11·73 grains of arsenic trisulphide were found, to how much arsenic trioxide does this correspond?

$$As_2S_3 + 9O = As_2O_3 + 3SO_2.$$

7. 50 grams of arsenic trioxide are heated with sulphur, what volume of sulphur dioxide at 39° C. is formed?

$$2As_2O_3 + 9S = 2As_2S_3 + 3SO_2.$$

8. Find the mass of 56 c.c. of the vapour of arsenic trichloride ($AsCl_3$) measured at 271·5° C.

9. A room 15 feet long and 10 feet wide and high is covered with a paper containing 0·78 grains of Scheele's green ($CuHAsO_3$) per square foot. How much arsenic is there in the room?

10. The vapour of arsenic trioxide is 13·85 times as heavy as air, find its double-density referred to hydrogen.

11. 4 litres of hydrogen sulphide at 13° C. are passed into a solution of arsenic trioxide, how much arsenic trisulphide precipitates?

$$3H_2S + As_2O_3 = 3H_2O + As_2S_3.$$

12. How much zinc is required to make a litre of hydrogen arsenide?

$$6Zn + 6H_2SO_4 + As_2O_3 = 6ZnSO_4 + 3H_2O + 2H_3As.$$

13. Find the percentage composition of Scheele's green ($CuHAsO_3$).

14. What does one litre of hydrogen arsenide (H_3As) weigh?

15. What volume of hydrogen arsenide at 15° C. can be formed from one gram of arsenic trioxide?

$$As_2O_3 + 6H_2 = 3H_2O + 2H_3As.$$

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16. 4·95 grams of arsenic trioxide are heated with hydrogen nitrate, what volume of nitrogen trioxide at 50° C. and 800 m.m. is given off?

$$As_2O_3 + 2HNO_3 + 2H_2O = 2H_3AsO_4 + N_2O_3.$$

17. What volume is occupied by 4 grams of cacodyl $As_2(CH_3)_4$ vapour at 210° C. and 780 m.m.?

18. Find the percentage composition of Schweinfurt green ($Cu2C_2H_3O_2 . 3CuAs_2O_4$).

19. What volume of hydrogen sulphide at 20° C. is required to precipitate the arsenic from 100 grams of arsenic trioxide ?

$$As_2O_3 + 3H_2S = 3H_2O + As_2S_3.$$

20. How much zinc is dissolved in forming 1·37 litres of hydrogen arsenide at 40° C. and 600 m.m. ?

$$6Zn + As_2O_3 + 6H_2SO_4 = 6ZnSO_4 + 3H_2O + 2H_3As.$$

21. Find the percentage composition of (α) realgar As_2S_2, (β) orpiment As_2S_3, (γ) arsenic pentasulphide As_2S_5.

22. The specific heat of arsenic is 0·0814, and 96·15 parts of arsenic combine with 3·85 parts of hydrogen. Find the atomic weight of the element.

CHAPTER XX.

ANTIMONY. $Sb = 120$.

BISMUTH. $Bi = 208$.

1. How much antimony is there in 1020 kilograms of the trisulphide (Sb_2S_3)?

2. A sheet of antimony (Δ 6·7) is 20 c.m. long, 10 c.m. wide, and 1 m.m. thick; find its mass.

3. What volume is occupied by 100 grams of (α) arsenic Δ 5·8, (β) antimony Δ 6·8, and (γ) bismuth Δ 9·9?

4. Type metal is an alloy of 80 parts of lead (Δ 11·3) and 20 parts of antimony (Δ 6·7). Find the density of the alloy, supposing that no change of volume takes place after the fusion.

5. How much common salt is required to give chlorine enough to convert 100 grams of antimony into the trichloride?

$$6NaCl + 3MnO_2 + 6H_2SO_4 = 3MnSO_4 + 3Na_2SO_4 + 6H_2O + 6Cl,$$
$$2Sb + 6Cl = 2SbCl_3.$$

6. 33·6 grams of antimony trisulphide are dissolved in hydrogen chloride. What volume of hydrogen sulphide under a pressure of 567 m.m. is evolved?

$$Sb_2S_3 + 6HCl = 2SbCl_3 + 3H_2S.$$

7. A piece of antimony was converted into the tribromide by absorbing 187 c.c. of bromine vapour. What was the mass of the antimony?

$$Sb + 3Br = SbBr_3.$$

8. According to Cooke 100 grams of antimony tribromide ($SbBr_3$) contain antimony 33·3335 per cent. and bromine 66·6665 per cent. If Br = 80, find the atomic weight of antimony.

9. What volume of hydrogen sulphide is evolved on dissolving 10 grams of antimony sulphide in hydrogen chloride?

$$Sb_2S_3 + 6HCl = 2SbCl_3 + 3H_2S.$$

10. How many grams do 20 litres of hydrogen antimonide (H_3Sb) measured at 15° C. weigh?

11. Bismuth melts at 264° C., what temperature is this on the Fahrenheit and on the Réaumur scale?

12. Find the percentage composition of the four oxides of bismuth, (α) Bi_2O_2, (β) Bi_2O_3, (γ)Bi_2O_4, (δ) Bi_2O_5.

13. What volume of oxygen at 30° C. is given off on heating 100 grams of bismuth pentoxide?

$$Bi_2O_5 = Bi_2O_4 + O.$$

14. Arcet's alloy consists of 5 parts of lead (Δ 11·45), 3 parts of tin (Δ 7·3) and 8 parts of bismuth (Δ 9·9). Find the density of the alloy supposing that its volume is equal to the sum of the volumes of its constituents.

15. Wood's alloy consists of 2 parts of lead (Δ 11·45), 4 parts of tin (Δ 7·3), 2 parts of cadmium (Δ 8·7), and 8 parts of bismuth (Δ 9·9). Find the density of the alloy supposing that the fusion produces no permanent change of volume.

16. One gram of hydrogen is contained in how many grams of hydrogen (α) silicide H_4Si, (β) phosphide H_3P, (γ) arsenide H_3As, (δ) antimonide H_3Sb?

17. What volume of chlorine is required to convert 100 grams of antimony into the pentachloride?

$$Sb + 5Cl = SbCl_5.$$

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18. What volume is occupied by 10 grams of trimethylstibene $Sb(CH_3)_3$ at 300° C.?

19. A cubic decimetre of antimony sulphide (Δ 4·62) is dissolved in hydrogen chloride, what volume of hydrogen sulphide at 30° C. and 800 m.m. is given off?

$$Sb_2S_3 + 6HCl = 2SbCl_3 + 3H_2S.$$

20. How much antimony is there in 15 litres of hydrogen antimonide (H_3Sb) measured at 100° C.?

21. 10 litres of hydrogen sulphide at 15° C. are passed into a solution of antimony trichloride, how much antimony trisulphide precipitates?

$$3H_2S + 2SbCl_3 = 6HCl + Sb_2S_3.$$

22. What volume of chlorine at 12° C. is required to convert 4·68 grams of bismuth trioxide into the pentoxide?

$$Bi_2O_3 + 2H_2O + 4Cl = 4HCl + Bi_2O_5.$$

23. Find the percentage composition of bismuth nitrate ($Bi\,3NO_3 . 5H_2O$).

24. Find the percentage composition of tartar emetic $2C_4H_4K(SbO)O_6 . H_2O$.

25. Schneider found 100 grams of bismuth trioxide to contain 89·655 grams of bismuth. Calculate the atomic weight of the element.

CHAPTER XXI.

THE GENERAL PROPERTIES OF THE METALS AND ALLOYS.

1. FIND the volume of 100 grams of (α) gold Δ 19·3, (β) lead Δ 11·4, (γ) sodium Δ 0·974.

2. Find the volume of 100 grams of (α) platinum Δ 21·5, (β) silver Δ 10·5, (γ) magnesium Δ 1·74.

3. What length of wire 2 m.m. in diameter can be drawn from a cubic decimetre of metal?

4. Gold leaf can be obtained $\frac{1}{200000}$ of an inch thick, what decimal of a m.m. is equal to this fraction of an inch?

5. Find the mass in kilograms of an iron (Δ 7·7) beam 12 feet long, 6 inches broad, and 9 inches deep.

6. A kilogram of copper (Δ 8·9), a kilogram of silver (Δ 10·5), and a kilogram of mercury (Δ 13·5) are placed in a vessel full of water. What volume of water overflows?

7. Find the value of 1000 square centimetres of gold (Δ 19·3) leaf, ·0001 c.m. thick at 2*s.* 9*d.* a gram.

8. Gold (Δ 19·3) leaf can be obtained $\frac{1}{10000}$ m.m. thick, what would be the length of the side of a square of such leaf containing one grain of gold?

9. Platinum (Δ 21·5) wire can be made $\frac{12}{10000}$ m.m. in diameter, how many grams would such a wire 21600 geographical miles in length weigh?

10. A steel wire 1 m.m. square will just carry 70 kilograms; how many tons will a rod of such steel one foot square sustain?

11. An iron wire 1 m.m. square will resist a pull of 70 kilograms, how many tons will a rod one inch square carry?

12. Find the mass of an iron (Δ 7·8) telegraph wire 2 m.m. in diameter and 16 kilometres long.

13. How many metres of wire $\frac{1}{5}$ m.m. in diameter can be made from one ounce Troy of platinum (Δ 21·5)? And at 40*s.* per ounce what is the price of the wire per foot?

14. A lead wire 1 m.m. square will just carry two kilograms. What is the length of an iron (Δ 7·25) weight 20 c.m. square, which a leaden rod 1 c.m. square will just carry?

15. How many grams does a sheet of iron (Δ 7·8) 1 m. square and $\frac{1}{2500}$ m.m. thick weigh?

16. Find the mass of a platinum (Δ 21·5) wire 1 d.m. long, and 0·25 m.m. in radius.

17. 112 kilograms of an alloy (Δ 8·784) of copper (Δ 9) and tin (Δ 7·32) consist of how many kilograms of copper and how many of tin?

18. A meteorite (Δ 7·5) contains 3 times its volume of hydrogen, how many times is the meteorite heavier than the hydrogen?

19. A cast iron (Δ 7·25) cube, each edge of which is 1 d.m. in length, floats upon mercury (Δ 13·596) with one face horizontal. How far is the cube immersed in the mercury?

20. An iron wire 2 m.m. in diameter will carry 250 kilos., a nickel wire of the same size will carry 375 kilos., and a similar wire of cobalt will carry 479 kilos. Find the diameter of a wire of each metal which will carry 1000 kilograms.

21. A glass tube 20 c.m. in length contains 121 grams of mercury (Δ 13·51), find its radius.

22. A spherical glass bulb is found to hold 509·52 grams of mercury (Δ 13·51), find its internal radius.

23. When weighing with brass (Δ 8·4) weights in air, what weight is apparently lost by the weights per gram?

24. Find the mass in tons of a square mile of coal (Δ 1·4) 30 feet thick.

25. How many tons of material (Δ 3) are raised from a coal-shaft 4 yards in diameter and 900 yards deep?

26. Gun-metal is composed of 10 parts of tin (Δ 7·3) and 90 parts of copper (Δ 8·9). Find the density of the alloy, supposing that its volume is equal to those of the two metals.

27. Britannia metal consists of 9 parts of tin (Δ 7·3) and 1 part of antimony (Δ 6·8). If the volume remains unchanged after the fusion, find the density of the alloy.

28. An alloy of equal parts of platinum (Δ 21·5) and copper (Δ 9) is found to have the same colour and density (Δ 19·5) as gold. In alloying 100 volumes of the two metals, what contraction takes place?

CHAPTER XXII.

POTASSIUM. K = 39·1.

1. FIND the mass of a ball of potassium (Δ 0·86) 2 c.m. in diameter.

2. With what volume of oxygen do 10 grams of potassium combine to form the oxides (α) K_2O, (β) K_2O_2, (γ) K_2O_3, (δ) K_2O_4?

3. Find the percentage composition of potassium, (α) hydrate HKO, (β) nitrate KNO_3, (γ) chlorate $KClO_3$.

4. What volume of carbon monoxide at 455° C. is given off during the separation of 100 grams of potassium?

$$K_2CO_3 + 2C = 3CO + 2K.$$

5. How many spherical pellets of potassium (Δ 0·86) each half an inch in diameter are there in an ounce avoirdupois of the metal?

6. A globule of potassium (Δ 0·86) 1 c.m. in diameter is thrown in small fragments into water, what volume of hydrogen at 15° C. is given off?

$$K + H_2O = HKO + H.$$

7. To make a kilogram of potassium hydrate how much (α) potassium carbonate and (β) calcium hydrate is required?

$$K_2CO_3 + H_2CaO_2 = CaCO_3 + 2HKO.$$

8. Find the mass of a stick of potassium hydrate (Δ 2·2) 1 c.m. across and 10 c.m. long.

9. How much potassium nitrate can be obtained from 1000 kilograms of potassium carbonate?

$$K_2CO_3 + 2HNO_3 = 2KNO_3 + H_2O + CO_2.$$

10. 10 grams of potassium bicarbonate are heated, what volume of carbon dioxide at 30° C. is given off?

$$2HKCO_3 = K_2CO_3 + H_2O + CO_2.$$

11. If 260 grams of potassium chlorate are heated, what volume of oxygen at 94·8° C. and 960 m.m. is evolved?

$$KClO_3 = KCl + 3O.$$

12. 4 grams of potassium and hydrogen carbonate are dissolved in hydrogen chloride, what volume of carbon dioxide at 52° C. is given off?

$$KHCO_3 + HCl = KCl + H_2O + CO_2.$$

13. A substance contains potassium 28·25 per cent., chlorine 25·64 per cent., and oxygen 46·11 per cent. Find its formula.

14. 100 grams of nitre are heated, what volume of oxygen at 39° C. is evolved?

$$KNO_3 = KNO_2 + O.$$

15. Find the mass of a potassium (Δ 0·86) wire 2 m.m. in diameter and 1 decim. long.

16. Potassium (Δ 0·86) absorbs 126 times its volume of hydrogen, find a formula for the body formed.

17. 20 grams of potassium nitrate are heated with potassium dichromate; what mass of gas is evolved, and what is the volume of each gas at 20° C.?

$$2KNO_3 + K_2Cr_2O_7 = 2K_2CrO_4 + 2NO_2 + O.$$

18. Find the percentage composition of potassium silicofluoride K_2SiF_6.

19. A gasogen holding 4 litres is charged by decomposing 4 ounces of hydrogen and potassium carbonate with tartaric acid, but the water is forgotten. If the temperature of the room be 10° C. what is the pressure of the gas in atmospheres?

$$2HKCO_3 + H_2\overline{T} = 2H_2O + K_2\overline{T} + 2CO_2.$$

20. Supposing that the decomposition of powder is expressed by the equation

$$S_2 + 6C + 2KNO_3 = 6CO_2 + 2N_2 + 2K_2S,$$

(α) What volume of gas at 0° C. is formed by 100 grams of powder, and (β) what volume would the gas occupy at 1000° C.?

21. 10 grams of potassium fluoride are heated with hydrogen sulphate, what volume of hydrogen fluoride at 90° C. is given off?

$$2KF + H_2SO_4 = K_2SO_4 + 2HF.$$

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22. What volume of oxygen at 15° C. is required to convert 10 grams of potassium into the tetroxide?

$$K_2 + O_4 = K_2O_4.$$

23. 5 grams of potassium tetroxide are thrown into water and the solution is boiled, what volume of oxygen at 100° C. is given off?

$$K_2O_4 + H_2O = 2HKO + 3O.$$

24. What volume of hydrogen sulphide at 15° C. and 730 m.m. must be passed into a solution of 100 grams of potassium bromate to reduce it to bromide?

$$2KBrO_3 + 6H_2S = 2KBr + 6H_2O + 6S.$$

25. Find the percentage composition of feldspar $K_2Al_2Si_6O_{16}$.

CHAPTER XXIII.

SODIUM. Na = 23.

1. FIND the percentage composition of (α) dry (Na_2CO_3) and (β) crystallized ($Na_2CO_310H_2O$) sodium carbonate.

2. A stick of sodium (Δ 0·97) is 1 c.m. square and 1 decim. long. Find its mass.

3. What volume of oxygen at 200° C. is required to convert 100 grams of sodium into the dioxide?

$$Na_2 + O_2 = Na_2O_2.$$

4. How much sodium can be obtained from 20 kilograms of sodium carbonate, and what volume of carbon monoxide is formed in the process?

$$Na_2CO_3 + 2C = 3CO + 2Na.$$

5. How much sodium can be obtained from one kilogram of sodium carbonate?

$$Na_2CO_3 + 2C = 3CO + 2Na.$$

6. Find the percentage composition of common salt ($NaCl$).

7. The specific heat of sodium is 0·2934, and 39·32 grams of sodium unite with 136·765 grams of bromine. Find the atomic weight of sodium.

$$Na + Br = NaBr.$$

8. How much slaked lime and sodium carbonate must be used to make a kilogram of sodium hydrate?

$$Na_2CO_3 + H_2CaO_2 = CaCO_3 + 2HNaO.$$

9. How many pounds of common salt are required to yield 500 lbs. of salt-cake?

$$2NaCl + H_2SO_4 = 2HCl + Na_2SO_4.$$

10. How much dry sodium carbonate can be made from 500 kilograms of common salt?

$$2NaCl + H_2SO_4 = 2HCl + Na_2SO_4.$$

$$Na_2SO_4 + CaCO_3 + 4C = 4CO + CaS + Na_2CO_3.$$

11. If 100 grams of common salt are decomposed by hydrogen sulphate, how much sodium sulphate, and what volume of hydrogen chloride is formed?

$$2NaCl + H_2SO_4 = Na_2SO_4 + 2HCl.$$

12. A sample of soda-ash is found to contain 56 per cent. of sodium oxide, how much sodium carbonate per cent. is there in the ash?

$$Na_2O + CO_2 = Na_2CO_3.$$

13. Find the percentage of sodium sulphate and of water in Glauber's salts ($Na_2SO_4 . 10H_2O$).

14. If 10 grams of sodium sulphite are dissolved in acid, what volume of sulphur dioxide at 12° C. is given off?

$$Na_2SO_3 + 2HCl = 2NaCl + H_2O + SO_2.$$

15. If 100 grams of sodium sulphate are heated with charcoal, how much sodium sulphide and what volume of carbon monoxide at 15° C. is formed?

$$Na_2SO_4 + 4C = Na_2S + 4CO.$$

16. 1000 kilograms of common salt are converted into

salt cake, how much sodium sulphate and what volume of hydrogen chloride gas is formed?

$$2NaCl + H_2SO_4 = Na_2SO_4 + 2HCl.$$

17. How many kilos. of soda crystals containing 3 per cent. of impurity, and how many kilos. of hydrochloric acid (Δ 1·21) containing 480 times its volume of the gas can be formed from the materials in the last question?

$$Na_2SO_4 + 4C + CaCO_3 = CaS + 4CO + Na_2CO_3,$$
$$Na_2CO_3 + 10H_2O = Na_2CO_3 . 10H_2O.$$

18. 10 grams of sodium and hydrogen sulphite are heated; what volume of sulphur dioxide is given off?

$$2NaHSO_3 = Na_2SO_3 + H_2O + SO_2.$$

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19. A cubical crystal of rock-salt (Δ 2·16) weighs 43·2 grams; find the length of its edge.

20. Sodium hydride (Δ 0·959) contains 46 parts of sodium (Δ ·97) and 1 part of hydrogen, find the apparent density of the solid hydrogen.

21. In trade analyses the atomic weight of sodium is often taken as 24 instead of 23; find the error per cent. thus introduced if the result be calculated (α) as sodium, (β) as sodium carbonate.

22. 1·221 grams of a mixture of potassium and sodium carbonates gave 1·231 grams of the mixed chlorides, from which 2·87 grams of silver chloride were formed. Find the percentage composition of the mixture.

$$[Na_2K_2]CO_3 + 2HCl = 2[NaK]Cl + H_2O + CO_2,$$
$$[NaK]Cl + AgNO_3 = AgCl + [NaK]NO_3.$$

23. What volume of carbon dioxide at 76·5° C. is absorbed in converting 10 kilos. of crystallized sodium carbonate into bicarbonate?

$$Na_2CO_3 10H_2O + CO_2 = 9H_2O + 2HNaCO_3.$$

24. What volume of carbon dioxide can be obtained from 3·72 grams of 'bicarbonate of soda' (*a*) by heating, (*β*) by the action of an acid?

$$2HNaCO_3 = Na_2CO_3 + H_2O + CO_2,$$

$$HNaCO_3 + HCl = NaCl + H_2O + CO_2.$$

CHAPTER XXIV.

AMMONIUM. $NH_4 = 18$.

1. A SUBSTANCE contains nitrogen 26·17 per cent., hydrogen 7·48 per cent., and chlorine 66·35 per cent; find its formula.

2. What is the mass of 4763 c.c. of solution of ammonia (Δ 0·855)?

3. 20 grams of ammonium sulphate are heated with lime; what volume of ammonia is given off?

$$(NH_4)_2SO_4 + CaO = CaSO_4 + H_2O + 2NH_3.$$

4. Water at 0° C. absorbs 1000 times its volume of ammonia; what mass of solution of ammonia (NH_3) can be formed from a litre of water?

5. Find the percentage composition of hydroxylamine NOH_3.

6. 2 grams of hydroxylamine are heated with solution of potassium hydrate, what volume of nitrogen and of ammonia at 21° C. is formed?

$$3NOH_3 = N_2 + NH_3 + 3H_2O.$$

7. Find the percentage composition of ammonium carbamate $(NH_3)_2CO_2$.

8. What volume of nitric oxide at 10° C. must be caused to combine with what volume of hydrogen at 20° C. to form 100 grams of hydroxylamine?

$$NO + 3H = NOH_3.$$

9. Find the formula of a body containing nitrogen 27·45 per cent., hydrogen 9·8 per cent., and sulphur 62·75 per cent.

10. Find the percentage composition of ammonium and hydrogen carbonate $(NH_4)_4H_23CO_3$.

11. How much ammonium chloride is there in a litre of a solution, 20 c.c. of which, after precipitation with platinum tetrachloride and ignition, gave 0·976 gram of platinum?

$$2NH_4Cl + PtCl_4 = Pt(NH_4)_2Cl_6,$$
$$Pt(NH_4)_2Cl_6 = Pt + 2NH_3 + 2HCl + 2Cl_2.$$

12. How many pints of solution of ammonia (Δ 0·88) weigh 4 lbs?

13. Find the percentage composition of ammonia-alum $(NH_4)_2Al_24SO_4 . 24H_2O$.

14. 40 grams of microcosmic salt are heated, how much sodium metaphosphate, what volume of ammonia at 15° C., and what volume of steam at 300° C. is formed?

$$Na(NH_4)HPO_4 . 4H_2O = NaPO_3 + NH_3 + 5H_2O.$$

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15. How much ammonium chloride must be heated with lime to make 10 litres of ammonia?

$$2NH_4Cl + CaO = CaCl_2 + H_2O + 2HN_3.$$

16. A kilogram of ammonium chloride is heated with lime, what volume of ammonia at 10° C. is given off?

$$2NH_4Cl + CaO = CaCl_2 + H_2O + 2NH_3.$$

17. A kilogram of ammonium nitrate is heated, what volume of nitrous oxide at 10° C. is evolved?

$$NH_4NO_3 = 2H_2O + N_2O.$$

18. A kilogram of ammonium nitrite is heated, what volume of nitrogen at 10° C. is given off?

$$NH_4NO_2 = 2H_2O + N_2.$$

19. What volume is occupied by the vapour of 10 grams of ammonium chloride (NH_4Cl) at 350° C. and 700 m.m.?

20. 10 grams of silver chloride saturated with ammonia are heated, what volume of ammonia at 50° C. is given off?

$$AgCl . 2NH_3 = AgCl + 2NH_3.$$

21. Water at 15° C. absorbs 740 times its volume of ammonia at the same temperature forming a solution (Δ 0·855); how much water is there in a litre of such a solution, and how much ammonium chloride is required to make it?

$$2NH_4Cl + CaO = CaCl_2 + H_2O + 2NH_3.$$

22. According to Stas, 100 grams of silver form 157·484 grams of silver nitrate. If Ag = 108, and O = 16, find the atomic weight of nitrogen.

$$Ag + HNO_3 = H + AgNO_3.$$

CHAPTER XXV.

CALCIUM. $Ca = 40$.

1. WHAT volume of hydrogen is given off on throwing a gram of calcium into water?

$$Ca + 2H_2O = CaH_2O_2 + H_2.$$

2. How many grams of chalk must be heated to form a ton of quick-lime?

$$CaCO_3 = CaO + CO_2.$$

3. 1000 grams of chalk are heated to redness, how much lime is left?

$$CaCO_3 = CaO + CO_2.$$

4. 1000 grams of calcium oxide form how much calcium hydrate?

$$CaO + H_2O = CaH_2O_2.$$

5. How much calcium is contained in 100 grams of (α) marble $CaCO_3$, (β) gypsum $CaSO_4 . 2H_2O$, (γ) fluorspar CaF_2, and (δ) calcium superphosphate CaH_42PO_4?

6. How many kilograms of calcium hydrate can be obtained by heating 2·726 kilos. of calc-spar to redness and throwing water on the residue?

$$CaCO_3 = CaO + CO_2,$$
$$CaO + H_2O = CaH_2O_2.$$

7. Find the mass in grams of a cubic mile of chalk (Δ 1·8).

8. A cubic metre of marble ($CaCO_3$ Δ 2·7) contains how many times its volume of gaseous carbon dioxide condensed in it?

9. A litre of water saturated with carbon dioxide dissolves ·88 grams of calcium carbonate. How many litres of water are required to dissolve 100 tons of calcium carbonate?

10. A body contains calcium 39·9 per cent., carbon 12·1 per cent., and oxygen 48 per cent. Find its formula.

11. 10 grams of marble are dissolved in hydrogen chloride, what volume of carbon dioxide at 30° C. is given off?

$$CaCO_3 + 2HCl = CaCl_2 + H_2O + CO_2.$$

12. 1000 kilograms of limestone are 'burnt', what volume of carbon dioxide at 300° C. is given off?

$$CaCO_3 = CaO + CO_2.$$

13. How much calcium sulphate can be formed from 11·1 grams of calcium chloride?

$$CaCl_2 + H_2SO_4 = 2HCl + CaSO_4.$$

14. How many grams does a pound of selenite lose when heated to 200° C.?

$$CaSO_4 2H_2O = CaSO_4 + 2H_2O.$$

15. A substance contains calcium 38·72 per cent., phosphorus 20 per cent., and oxygen 41·28 per cent. Find its formula.

16. A salt contains calcium 27·4 per cent., carbon 16·44 per cent., oxygen 43·84 per cent., and water 12·33 per cent. Find its formula.

17. What volume of chlorine at 21° C. must be used to make 1000 grams of bleaching powder, and how much manganese dioxide is required to obtain the chlorine?

$$MnO_2 + 4HCl = MnCl_2 + 2H_2O + Cl_2,$$
$$CaO + Cl_2 = CaOCl_2.$$

18. Calcium hydrate is soluble in 720 times its mass of cold, and in 1300 times its mass of boiling water. How much of the hydrate precipitates on boiling a litre of the saturated solution?

19. How many c.c. of water must be added to 100 grams of plaster of Paris to make it set?

$$CaSO_4 + 2H_2O = CaSO_4 . 2H_2O.$$

20. How much water do 100 grams of calcium chloride combine with in crystallizing?

$$CaCl_2 + 6H_2O = CaCl_2 . 6H_2O.$$

21. How many grams of calcium chloride ($CaCl_2$) must be dissolved in a litre of water to be equivalent to a *hard* water containing x grains of calcium carbonate ($CaCO_3$) per gallon?

22. 1000 grams of sea-water contain 1·33 grams of calcium sulphate, and 0·047 grams of calcium carbonate. How much sea-water would give 3·24 grams of calcium oxalate?

$$CaSO_4 + (NH_4)_2C_2O_4 = (NH_4)_2 SO_4 + CaC_2O_4,$$
$$CaCO_3 + (NH_4)_2C_2H_4 = (NH_4)_2CO_3 + CaC_2O_4.$$

23. 100 grams of bleaching powder are heated with water and cobalt oxide, what volume of oxygen at 21° C. is evolved?

$$2CaOCl_2 = 2CaCl_2 + O_2.$$

24. A cistern 10 feet square and 6 feet deep contains water saturated with calcium sulphate, which is soluble in 400 times its mass of water. How many kilograms of the salt are there in the cistern?

25. 700 c.c. of water dissolve 1 gram of calcium hydrate and 1·26 litres of carbon dioxide. If 700 c.c. of each solution be mixed, what mass of which substance remains in solution?

$$CaH_2O_2 + CO_2 = CaCO_3 + H_2O.$$

26. A litre of air at 12°.C. when shaken up with lime-water gave 0·0017 gram of calcium carbonate. Find the percentage by volume of carbon dioxide in the air.

$$CaH_2O_2 + CO_2 = CaCO_3 + H_2O.$$

CHAPTER XXVI.

STRONTIUM. Sr = 87·6.

BARIUM. Ba = 137.

1. FIND the percentage composition of (α) Strontianite $SrCO_3$, (β) Celestine $SrSO_4$, (γ) Witherite $BaCO_3$, and (δ) Heavy Spar $BaSO_4$.

2. A strontium (Δ 2·54) wire 10 c.m. long weighs 2·6 grams, find its radius.

3. What is the probable specific heat of barium ?

4. 1000 grams of strontium nitrate are heated, how much strontia is left ?

$$Sr2NO_3 = SrO + 2NO_2 + O.$$

5. How much baryta can be made from 1000 grams of barium nitrate ?

$$Ba2NO_3 = BaO + 2NO_2 + O.$$

6. 2 grams of strontium are obtained by passing a current of electricity through the fused chloride, what volume of chlorine at 15° C. is set free ?

$$SrCl_2 = Sr + Cl_2.$$

7. A litre of carbon dioxide at 15° C. is drawn through baryta water; how much barium carbonate precipitates ?

$$H_2BaO_2 + CO_2 = H_2O + BaCO_3.$$

8. One gram of calcium sulphate will form how much barium sulphate?

$$CaSO_4 + BaCl_2 = CaCl_2 + BaSO_4.$$

9. 0·591 gram of witherite gave 0·699 gram of barium sulphate; find the percentage of barium in the witherite.

$$BaCO_3 + H_2SO_4 = H_2O + CO_2 + BaSO_4.$$

10. 100 grams of barium monoxide are heated in oxygen, what volume of oxygen at 21° C. is absorbed?

$$BaO + O = BaO_2.$$

11. How many cubic metres would a ton of barium sulphate Δ 4·6 occupy?

12. 100 grams of water dissolve 5 grams of crystallized barium hydrate, how much hydrogen sulphate is required to precipitate the barium from 20 grams of such a solution?

$$BaH_2O_2 . 8H_2O + H_2SO_4 = 10H_2O + BaSO_4.$$

13. Crystallized barium hydrate ($H_2BaO_2 . 8H_2O$) is soluble in 20 times its mass of cold water. How much barium hydrate is there in 100 grams of the saturated solution?

14. A solution contains 100 grams of crystallized barium chloride per litre, how much hydrogen sulphate will 1 c.c. of the solution precipitate?

$$BaCl_2 . 2H_2O + H_2SO_4 = 2H_2O + 2HCl + BaSO_4.$$

15. What volume of sulphur dioxide at 39° C. must be passed over 100 grams of heated barium dioxide to convert it into sulphate?

$$SO_2 + BaO_2 = BaSO_4.$$

16. 59 litres of air are drawn over heated baryta, how much barium dioxide is formed?

$$BaO + O = BaO_2.$$

17. 20 grams of witherite are dissolved in hydrogen chloride, how much crystallized barium chloride and what volume of carbon dioxide is formed?

$$BaCO_3 + 2HCl + H_2O = CO_2 + BaCl_2 . 2H_2O.$$

18. Crystallized strontium hydrate is soluble in 50 times its mass of water, how much hydrogen sulphate will 100 grams of such a solution precipitate?

$$H_2SrO_2 . 8H_2O + H_2SO_4 = 10H_2O + SrSO_4.$$

19. If air contains 0·037 per cent. by volume of carbon dioxide, find the mass of the precipitate produced on drawing 1000 litres of air through baryta water,

$$CO_2 + H_2BaO_2 = H_2O + BaCO_3.$$

20. 100 grams of hydrated barium dioxide are suspended in water, what volume of carbon dioxide at 13° C. is required to precipitate the barium?

$$BaO_2 . 6H_2O + CO_2 = BaCO_3 + H_2O_2 + 5H_2O.$$

21. What volume of carbon dioxide at 10° C. is required to precipitate the barium from a solution of 100 grams of crystallized barium chloride in presence of ammonia?

$$2NH_3 + BaCl_2 2H_2O + CO_2 = BaCO_3 + H_2O + 2NH_4Cl.$$

22. If 14 grams of barium dioxide are heated, what volume of oxygen at 15° C. and 700 m.m. is given off?

$$BaO_2 = BaO + O.$$

23. On the addition of ammonium carbonate to a mixture of calcium and barium chlorides, the precipitate weighed 10 grams. On redissolving the precipitate and adding ammonium sulphate, the precipitate weighed 12

grams. How much barium and how much calcium was present?

$$4NH_3 + [BaCa]\,Cl_2 + 2H_2O + 2CO_2 = 4NH_4Cl + [BaCa]\,CO_3.$$
$$[BaCa]\,Cl_2 + 2H_2SO_4 = 4HCl + [BaCa]\,SO_4.$$

24. According to Marignac, 10 grams of crystallized strontium chloride give 6·8855 grams of strontium sulphate. Find the atomic weight of strontium.

$$SrCl_2 . 6H_2O + H_2SO_4 = 6H_2O + 2HCl + SrSO_4.$$

CHAPTER XXVII.

ALUMINIUM. $Al = 27$.

1. How much aluminium is there in 100 grams of (α) cryolite $Al_2Na_6F_{12}$, (β) common alum $K_2Al_24SO_4 . 24H_2O$?

2. A sheet of aluminium (Δ 2·67) is 1 m.m. thick, 1 d.m. across, and 1 m. long. Find its mass.

3. 5·4 grams of aluminium are dissolved in potassium hydrate, what volume of hydrogen is given off?

$$Al_2 + 2HKO + 2H_2O = 2KAlO_2 + 6H.$$

4. What volume of oxygen is required to burn 10 grams of aluminium?

$$Al_2 + 3O = Al_2O_3.$$

5. How much aluminium is there in 100 grams of turquois $(Al_2P_2O_8 . H_6Al_2O_6 . 2H_2O)$?

6. What volume of oxygen at 15° C. is required to burn 50 grams of aluminium?

$$Al_2 + 3O = Al_2O_3.$$

7. 50 grams of oxygen are heated with 54 grams of aluminium, what volume of oxygen is left uncombined?

$$Al_2 + 3O = Al_2O_3.$$

8. 100 grams of ammonia-alum are heated, how much alumina is left?

$$(NH_4)_2Al_24SO_4 . 24H_2O = (NH_4)_2SO_4 + Al_2O_3 + 3H_2SO_4 + 21H_2O.$$

9. How much alumina and how much silica is there in 100 grams of clay ($Al_2O_3 . 2SiO_2$)?

10. How much potassium-alum ($K_2Al_24SO_4 . 24H_2O$) can be made from 1000 000 grams of clay ($Al_2O_3 . 2SiO_2$)?

11. What volume of ammonia can be obtained from 100 grams of ammonia-alum?

$$(NH_4)_2Al_24SO_4 . 24H_2O + 2HKO = K_2Al_24SO_4 . 24H_2O + 2H_2O + 2NH_3.$$

12. 7·339 litres of the vapour of aluminium chloride at 546° C. are passed over heated sodium, how much aluminium is set free?

$$Al_2Cl_6 + 6Na = 6NaCl + 2Al.$$

13. A mineral was found to contain alumina 68·31 per cent., ferric oxide 3·37 per cent., ferrous oxide 2·06 per cent., and magnesia 26·26 per cent. Find its formula.

14. Find the percentage composition of aluminium and sodium chloride. ($Al_2Na_2Cl_8$.)

15. Find the percentage composition of diaspore. ($Al_2O_3 . H_2O$.)

16. 5 grams of aluminium are heated in sulphur vapour. How much aluminium sulphide is formed?

$$Al_2 + 3S = Al_2S_3.$$

17. 10 kilograms of alumina will form how much potash-alum?

$$Al_2O_3 + 3H_2SO_4 + K_2SO_4 + 21H_2O = K_2Al_24SO_4 . 24H_2O.$$

18. The vapour of aluminium chloride is 9·34 times as heavy as air, find its molecular weight.

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19. 20 grams of cryolite are heated with hydrogen sulphate, what volume of hydrogen fluoride at 20° C. is given off?

$$Na_6Al_2F_{12} + 6H_2SO_4 = 3Na_2SO_4 + Al_23SO_4 + 12HF.$$

20. Find the mass of 10 litres of the vapour of aluminium chloride (Al_2Cl_6) measured at 300° C.

21. Aluminium bronze contains 10 per cent. of aluminium (Δ 2·6) and 90 per cent. of copper (Δ 8·9). Find the density of the alloy supposing that no change of volume has taken place.

22. What volume of chlorine at 15° C. and 750 m.m. is required to convert 10 grams of alumina into aluminium chloride?

$$Al_2O_3 + 3C + 6Cl = 3CO + Al_2Cl_6.$$

23. Find a formula for ultramarine which contains aluminium 14·5 per cent., silicon 17·5 per cent., sodium 16 per cent., sulphur 14·2 per cent., and oxygen 37·8 per cent.

24. 1 gram of aluminium when dissolved in hydrogen chloride gave 1·271 lit. of hydrogen at 10° C. Find the atomic weight of aluminium.

$$Al_2 + 6HCl = Al_2Cl_6 + 6H.$$

25. Steam is passed over 20 grams of gently heated aluminium chloride, what volume of hydrogen chloride at 150° C. is formed?

$$Al_2Cl_6 + 3H_2O = Al_2O_3 + 6HCl.$$

26. What volume of aluminium (Δ 2·6) must be dissolved in potassium hydrate to make a litre of hydrogen at 12° C.?

$$Al_2 + 2HKO + 2H_2O = 2KAlO_2 + 3H_2.$$

27. If 10 grams of aluminium sulphide are thrown into water, what volume of hydrogen sulphide at 15° C. and 800 m.m. is given off?

$$Al_2S_3 + 3H_2O = Al_2O_3 + 3H_2S.$$

28. Find a formula for Stourbridge fire-clay which contains silica 64·1 per cent., alumina 23·15 per cent., ferrous oxide 1·85 per cent., magnesia 0·95 per cent., and water 10 per cent.

CHAPTER XXVIII.

MAGNESIUM. $Mg = 24$.

1. How much magnesium is there in 1000 grams of (α) magnesite $MgCO_3$, and (β) Epsom salts $MgSO_4 . 7H_2O$?

2. How many yards of wire $\frac{1}{12}$ inch in diameter can be made from an ounce of magnesium (Δ 1·74)?

3. What volume of oxygen is required to burn 4 grams of magnesium?

$$Mg + O = MgO.$$

4. 10 grams of magnesium are dissolved in hydrogen chloride, what volume of hydrogen is given off?

$$Mg + 2HCl = MgCl_2 + H_2.$$

5. 100 grams of potassium are heated with magnesium chloride, how much magnesium is formed?

$$K_2 + MgCl_2 = 2KCl + Mg.$$

6. 40 grams of magnesite are dissolved in hydrogen chloride, what volume of carbon dioxide is given off?

$$MgCO_3 + 2HCl = MgCl_2 + H_2O + CO_2.$$

7. 10 grams of magnesite are dissolved in acid, what volume of carbon dioxide at 26° C. is evolved?

$$MgCO_3 + 2HCl = MgCl_2 + H_2O + CO_2.$$

8. A dolomite contains 12 per cent. of magnesium carbonate, how many kilograms of Epsom salts could be made from 120 kilograms of it?

$$MgCO_3 + H_2SO_4 + 6H_2O = CO_2 + MgSO_4 . 7H_2O.$$

9. Find the percentage composition of magnesium pyrophosphate ($Mg_2P_2O_7$).

10. Find the percentage composition of meerschaum ($Mg_2Si_3O_84H_2O$).

11. Find the percentage composition of dolomite ($CaMg2CO_3$).

12. Find the percentage composition of serpentine ($Mg_3Si_2O_7 . 2H_2O$).

13. How much crystallized magnesium sulphate can be obtained by dissolving 1000 grams of magnesite in dilute hydrogen sulphate, and what volume of carbon dioxide is evolved?

$$MgCO_3 + H_2SO_4 + 6H_2O = MgSO_4 . 7H_2O + CO_2.$$

14. What masses of (α) sodium Na_2CO_3, (β) calcium $CaCO_3$, and (γ) magnesium $MgCO_3$ carbonates contain one litre of carbon dioxide?

15. 40 grams of magnesium are dissolved in dilute hydrogen chloride, what volume of hydrogen at 21° C. and 380 m.m. is given off?

$$Mg + 2HCl = MgCl_2 + H_2.$$

16. Equal masses of magnesium (Δ 1·7), zinc (Δ 7), and cadmium (Δ 8·5) are alloyed. If no change of volume takes place, find the density of the alloy.

17. Equal masses of magnesium (Δ 1·7), and of cadmium (Δ 8·5) are fused together. If no change of volume takes place, find the density of the alloy.

18. 4 grams of dolomite when strongly heated gave 938·6 c.c. of carbon dioxide. Find the percentage of calcium and of magnesium carbonate in the dolomite?

$$CaCO_3 = CaO + CO_2.$$
$$MgCO_3 = MgO + CO_2.$$

19. 0·2 gram of magnesium, when dissolved in acid gave 195·5 c.c. of hydrogen at 13° C. What is the atomic weight of magnesium?

$$Mg + 2HCl = MgCl_2 + H_2.$$

20. 0·1 gram of magnesium when dissolved in acid gave 100 c.c. of hydrogen at 12° C. the barometer standing at 758·8 m.m., and the column of water in the tube being 250 m.m. Find the equivalent of magnesium.

$$mg + h\,cl = mg\,cl + h.$$

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21. What volume of hydrogen at 13° C. and 740 m.m. is given off on dissolving 0·02 grams of magnesium in dilute acid?

$$Mg + 2HCl = MgCl_2 + H_2.$$

22. 2 grams of magnesium are prepared by the electrolysis of the fused chloride, what volume of chlorine at 15° C. and 745 m.m. is given off?

$$MgCl_2 = Mg + Cl_2.$$

23. What volume of nitrogen at 20° C. and 780 m.m. will combine with 50 grams of magnesium?

$$3Mg + 2N = Mg_3N_2.$$

24. What volume of hydrogen measured over water at 14° C. and 760 m.m. is set free on dissolving 0·2 grams of magnesium in acid?

$$Mg + 2HCl = MgCl_2 + H_2.$$

CHAPTER XXIX.

ZINC. Zn. = 65.

CADMIUM. Cd = 112.

1. FIND the percentage composition of (α) zinc blende ZnS and (β) calamine $ZnCO_3$.

2. Zinc melts at 773° F. and boils at 1904° F., what are these temperatures on the Centigrade scale?

3. Find the formula of a substance containing zinc 54·17 per cent., silicon 11·67 per cent., oxygen 26·67 per cent., and water 7·5 per cent.

4. How much zinc white can be made from 1000 grams of zinc, and what volume of air is required?

$$Zn + O = ZnO.$$

5. 20 grams of zinc are dissolved in dilute hydrogen sulphate, what volume of hydrogen is given off?

$$Zn + H_2SO_4 = ZnSO_4 + H_2.$$

6. Find the percentage composition of cadmium sulphide CdS.

7. How much cadmium iodide can be made from 56 grams of cadmium?

$$Cd + 2I = CdI_2.$$

8. How many pounds of zinc can be dissolved by 600 pounds of hydrogen sulphate diluted with water?

$$Zn + H_2SO_4 = ZnSO_4 + H_2.$$

9. How much zinc can be dissolved by 450 pounds of solution of hydrogen chloride containing 30 per cent. of real acid?

$$Zn + 2HCl = ZnCl_2 + H_2.$$

10. What volume of air is required to oxidize 1000 kilograms of zinc-blende?

$$2ZnS + 3O_2 = 2ZnO + 2SO_2.$$

11. Cadmium becomes brittle at 180° F., melts at 242° F., and boils at 1580° F. What are these temperatures on the Centigrade scale?

12. How much crystallized cadmium bromide can be made from 100 grams of cadmium, and what volume of hydrogen is given off?

$$Cd + 2HBr + 4H_2O = CdBr_2 4H_2O + H_2.$$

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13. A metallic chloride is found to contain 38·66 per cent. of chlorine, and its vapour is 8 times as heavy as air. Find the atomic weight of the metal and the formula of the chloride.

14. How much zinc must be dissolved in dilute hydrogen sulphate to fill a wedge-shaped india-rubber bag 1 m. long, 60 c.m. broad, and 340 m.m. deep at the thickest end, with hydrogen at 15° C., and 780 m.m.?

$$Zn + H_2SO_4 = ZnSO_4 + H_2.$$

15. What volume of hydrogen measured over water at 15° C. and 760 m.m. is set free on dissolving 0·5 grams of zinc in acid?

$$Zn + 2HCl = ZnCl_2 + H_2.$$

16. Find the formula of a substance containing zinc 58·56 per cent., carbon 4·05 per cent., oxygen 25·23 per cent., and water 12·16 per cent.

17. 4 litres of chlorine at 30° C. and 770 m.m. are passed over heated zinc, how much zinc chloride is formed?

$$Zn + Cl_2 = ZnCl_2.$$

18. Brass consists of two parts of copper alloyed with one part of zinc. Find an approximate formula for it.

19. 0·5 grams of zinc when dissolved in acid gave 183 c.c. of hydrogen measured over water at 9° C., the barometer standing at 748 m.m. Find the equivalent of the metal.

$$zn + h\,cl = zn\,cl + h.$$

20. What volume of hydrogen can be obtained by dissolving 471 grams of zinc in acid, and how long will the gas take to diffuse through an apparatus which allows 16 litres of nitric oxide (NO) to pass in 100 seconds?

$$Zn + 2HCl = ZnCl_2 + H_2.$$

21. A quantity of potassium nitrate is boiled with zinc, iron, and potassium hydrate, how much zinc is dissolved during the evolution of one litre of ammonia at 10° C. and 730 m.m.?

$$14HKO + 8Zn + 2KNO_3 = 8K_2ZnO_2 + 4H_2O + 2NH_3.$$

22. A substance contains zinc 52·84 per cent., carbon 39·03 per cent., and hydrogen 8·13 per cent. Find its formula.

CHAPTER XXX.

MANGANESE. Mn = 55.

1. FIND the percentage of manganese in (α) pyrolusite MnO_2, (β) Braunite Mn_2O_3.

2. Manganese has the specific heat 0·114, and 69·92 grams of it combine with 30·38 grams of oxygen; find the atomic weight of the metal.

3. A pellet of manganese weighed in ether (Δ ·7024) 14·6212 grams, and in chloroform (Δ 1·5252) 12·9756 grams, find the density of the metal.

4. According to v. Hauer, manganous sulphate ($MnSO_4$) contains 42·39 per cent. of oxygen. Find the atomic weight of the metal.

5. What is the mass of a manganese wire (Δ 8) 1 m. long and 1 m.m. in radius?

6. 100 grams of manganous oxide are heated to whiteness with charcoal, how much manganese and what volume of carbon monoxide are formed?

$$MnO + C = Mn + CO.$$

7. What volume of oxygen at 12° C. can be made by heating 500 grams of manganese dioxide?

$$3MnO_2 = Mn_3O_4 + O_2.$$

8. What volume of oxygen at 750 m.m. can be made by heating 500 grams of manganese dioxide with hydrogen sulphate?

$$MnO_2 + H_2SO_4 = MnSO_4 + H_2O + O.$$

9. How many grams of oxygen are there in 100 grams of potassium permanganate ($K_2Mn_2O_8$)?

10. How much manganese ore containing 85 per cent. of the dioxide is required to give 300 lbs. of chlorine?

$$MnO_2 + 4HCl = MnCl_2 + 2H_2O + Cl_2.$$

11. Find the percentage composition of manganese-alum ($K_2Mn_24SO_4 . 24H_2O$).

12. How much manganese dioxide can be made from a cubic metre of "red liquor" containing 0·3 gram of manganous chloride in 1 c.c.?

$$MnCl_2 + H_2CaO_2 + O = CaCl_2 + H_2O + MnO_2.$$

13. Find the percentage composition of manganese blende (MnS).

14. How much manganous sulphate can be obtained from a kilogram of manganese dioxide?

$$MnO_2 + H_2SO_4 = H_2O + O + MnSO_4.$$

15. 487 grams of manganese dioxide are heated, what volume of oxygen at 15° C. is given off?

$$3MnO_2 = Mn_3O_4 + O_2.$$

16. 10 grams of manganese ore mixed with hydrogen sulphate oxidized 10·953 grams of hydrogen oxalate. Find the percentage of manganese dioxide in the ore.

$$MnO_2 + C_2H_2O_4 . 2H_2O + H_2SO_4 = MnSO_4 + 2CO_2 + 4H_2O.$$

17. A sample of pyrolusite is found to contain 34 per cent. of oxygen as the dioxide. What volume of chlorine can be obtained by heating 20 grams of the mineral with hydrogen chloride?

$$MnO_2 + 4HCl = 2H_2O + MnCl_2 + Cl_2.$$

18. 4·9435 grams of commercial manganese dioxide, when warmed with hydrogen sulphate and oxalate, caused the evolution of 2·18 grams of carbon dioxide. Find the percentage of real dioxide in the sample.

$$MnO_2 + C_2H_2O_4 . 2H_2O + H_2SO_4 = MnSO_4 + 4H_2O + 2CO_2.$$

19. 0·4 gram of "manganese" containing 90 per cent. of real dioxide is distilled with hydrogen chloride. How much iodine is set free on leading the evolved chlorine into solution of potassium iodide?

$$MnO_2 + 4HCl = 2H_2O + MnCl_2 + Cl_2.$$
$$Cl_2 + 2KI = 2KCl + I_2.$$

20. 2 grams of dry manganous sulphate are dissolved and precipitated by barium chloride. What will the mass of the precipitate be if (i) Mn = 55, and (ii) Mn = 54?

$$MnSO_4 + BaCl_2 = MnCl_2 + BaSO_4.$$

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21. How much manganese dioxide must be heated to form 1000 litres of oxygen at 20° C.?

$$3MnO_2 = Mn_3O_4 + O_2.$$

22. What volume of air is required to oxidize the manganese in 1000 litres of 'red liquor' containing 100 grams of manganous chloride per litre?

$$MnCl_2 + H_2CaO_2 + O = H_2O + CaCl_2 + MnO_2.$$

23. How much manganese dioxide is required to give 2·7 litres of oxygen at 14° C. and 754 m.m.?

$$3MnO_2 = Mn_3O_4 + O_2.$$

24. A gram of partially dried hydrogen oxalate when warmed with hydrogen sulphate and manganese dioxide gave 492 c.c. of carbon dioxide measured over water at 20° C. and 757·4 m.m. Find the percentage of water still left in the oxalate.

$$C_2H_2O_4 + H_2SO_4 + MnO_2 = MnSO_4 + 2H_2O + 2CO_2.$$

CHAPTER XXXI.

IRON. Fe = 56.

1. FIND the mass of a cylindrical cast-iron (Δ 7·25) cannon-bolt, 10 c.m. in diameter and 15 c.m. long.

2. Find the mass of a cast-iron (Δ 7·25) hexagonal cannon-bolt, each side of the hexagon being 2 c.m. and its length 20 c.m. (The area of a hexagon is 2·598 times the square of a side.)

3. An empty spherical Mallet shell (Δ 7·25) is a yard in diameter and two inches thick. Find its mass in kilograms.

4. A wrought-iron (Δ 7·8) cube weighs 1 kilogram, find the length of its edge in centimetres.

5. Find the mass of a cast-iron (Δ 7·25) grape-shot 2 c.m. in diameter.

6. How many grams does a cubic foot of pure iron (Δ 7·88) weigh more than a cubic foot of steel (Δ 7·75) ?

7. Find the mass in tons of a forged steel cylinder (Δ 7·8) 13 metres long and a metre in diameter.

8. The best Low Moor iron will bear a pull of 64 200 lbs. per square inch, how many kilos. will a wire 2 m.m. in diameter carry ?

9. On January 18th 1881 the barometer in London stood at 30·961 inches. How many m.m. high was it?

10. An iron (Δ 7·8) armour plate is 12 feet long, 4 feet wide and 6 inches thick, find its mass in tons.

11. What volume of hydrogen at 15° C. and 730 m.m. is required to reduce 273 grams of ferric oxide?

$$Fe_2O_3 + 6H = 3H_2O + 2Fe.$$

12. How much ferrous oxide can be made by heating 147 grams of ferrous oxalate in hydrogen?

$$FeC_2O_4 2H_2O = 2H_2O + CO_2 + CO + FeO.$$

13. What volume of hydrogen is evolved during the formation of 463 grams of crystallized ferrous chloride?

$$Fe + 2HCl + 4H_2O = FeCl_2 . 4H_2O + H_2.$$

14. What volume of hydrogen at 13° C. is required to reduce 894 grams of ferric oxide?

$$Fe_2O_3 + 6H = 3H_2O + 2Fe.$$

15. Find the percentage composition of potassium ferrate (K_2FeO_4).

16. How many tons of coke containing 97 per cent. of carbon are required to reduce 388 tons of hematite?

$$Fe_2O_3 + 3C = 3CO + 2Fe.$$

17. Find the percentage composition of ferrous oxalate ($FeC_2O_4 . 2H_2O$).

18. Find the percentage composition of hydrated ferrous carbonate ($FeCO_3 . H_2O$).

19. How many cubic metres of carbon monoxide at 1200° C. are evolved in making a ton of iron from ferrous carbonate?

$$FeCO_3 + 2C = 3CO + Fe.$$

20. How much colcothar and Nordhausen sulphuric acid can be made from 348 tons of green vitriol?

$$6FeSO_4 . 7H_2O + 3O = 39H_2O + Fe_2O_3 + 2Fe_23SO_4 . 3H_2O.$$
$$Fe_2O_3 + 2Fe_23SO_4 . 3H_2O = 3Fe_2O_3 + 3H_2S_2O_7.$$

21. What volume of oxygen is required to burn 10 grams of iron?

$$3Fe + 4O = Fe_3O_4.$$

22. Find the formula of a salt containing iron 28 per cent., sulphur 24 per cent. and oxygen 48 per cent.

23. Crystallized ferric and ammonium sulphate contains $\frac{1}{7}$ of its mass of iron, find its formula.

24. How many grams does a cubic foot of iron (Δ 7·7) weigh?

25. What is the percentage of iron and of sulphur in iron pyrites (FeS_2)?

26. What volume of oxygen is required to convert 100 grams of ferrous into ferric oxide?

$$2FeO + O = Fe_2O_3.$$

27. Calculate the percentage composition of the carbides of iron (α) Fe_4C, (β) Fe_8C.

28. Calculate the percentage composition of crystallized ferrous sulphate ($FeSO_4 . 7H_2O$).

29. How many grams of ferrous sulphide are required to give 750 c.c. of hydrogen sulphide?

$$FeS + 2HCl = FeCl_2 + H_2S.$$

30. How much crystallized ferrous sulphate can be made from 10 grams of iron?

$$Fe + H_2SO_4 + 7H_2O = H_2 + FeSO_4 . 7H_2O.$$

31. An iron (Δ 7·7) wire 1 m.m. in diameter is burnt in a cylinder of oxygen. After the combustion the water rises in the cylinder through a height equal to the length of wire burnt. Find the radius of the cylinder.

$$3Fe + 4O = Fe_3O_4.$$

32. The mass of a litre of the vapour of ferric chloride reduced by calculation to 0° C. and 760 m.m. is 14·56 grams. Find its molecular weight.

33. An iron ore contains 59·89 per cent. of iron as ferric oxide, and 14·44 per cent. of water, find its formula.

34. Find the percentage composition of magnetic pyrites (Fe_3S_4).

35. How many tons of hydrogen sulphate can be made from 10 tons of pyrites?

$$2FeS_2 + 15O + 4H_2O = Fe_2O_3 + 4H_2SO_4.$$

36. Find the percentage composition of pyrrhotin if its formula be (α) Fe_5S_6, (β) Fe_6S_7.

37. Iron nitride obtained by heating ferrous chloride in ammonia contains 9·3 per cent. of nitrogen. Find its formula.

38. What volume of sulphur dioxide at 39° C. can be obtained by passing air over 100 grams of ferrous disulphide heated to redness?

$$2FeS_2 + 11O = Fe_2O_3 + 4SO_2.$$

39. 14 grams of iron are dissolved in hydrogen chloride, what volume of hydrogen at 13° C. is given off?

$$Fe + 2HCl = FeCl_2 + H_2.$$

40. Two litres of gaseous hydrogen chloride are passed over heated iron, how much ferrous chloride is formed?

$$Fe + 2HCl = FeCl_2 + H_2.$$

41. 347 grams of ferrous sulphide are dissolved in hydrogen chloride, what volume of hydrogen sulphide at 11° C. is given off?

$$FeS + 2HCl = FeCl_2 + H_2S.$$

42. What volume of hydrogen sulphide at 17° C. is evolved on dissolving 489 grams of ferrous sulphide in acid?

$$FeS + H_2SO_4 = FeSO_4 + H_2S.$$

43. What volume of hydrogen at 13° C. is evolved during the solution in dilute hydrogen sulphate of sufficient iron to form 1463 grams of crystallized ferrous sulphate?

$$Fe + H_2SO_4 + 7H_2O = FeSO_4 . 7H_2O + H_2.$$

44. How much ferric oxide is obtained on drying the precipitate produced by ammonia in a solution of 187 grams of crystallized ferric nitrate?

$$Fe_26NO_3 . 18H_2O + 6NH_3 = 15H_2O + 6NH_4NO_3 + Fe_2O_3.$$

45. How much sulphur precipitates on passing 1·7 litres of hydrogen sulphide at 17° C. through an excess of solution of ferric chloride?

$$Fe_2Cl_6 + H_2S = 2FeCl_2 + 2HCl + S.$$

46. A salt contains iron 14 per cent., iodine 63·5 per cent., and water 22·5 per cent., find its formula.

47. During the solution of a gram of iron in dilute hydrogen chloride, 389·74 c.c. of hydrogen at 14° C. and 820 m.m. were evolved. Find the equivalent of iron.

$$fe + h\,cl = fe\,cl + h.$$

48. How much iron will one gram of potassium permanganate convert from ferrous into ferric salt?

$$10FeSO_4 + K_2Mn_2O_8 + 8H_2SO_4$$
$$= 5Fe_23SO_4 + K_2SO_4 + 2MnSO_4 + 8H_2O.$$

49. If 3 grams of potassium permanganate are dissolved in a litre of water, to how much iron does 1 c.c. of the solution correspond?

$$K_2Mn_2O_8 + 10Fe + 18H_2SO_4 = 5Fe_23SO_4 + K_2SO_4 + 2MnSO_4 + 8H_2O.$$

50. A solution of 0·985 gram of black-band ironstone required 55·5 c.c. of a solution of potassium permanganate, containing 3 grams of the salt per litre. What is the percentage of iron in the ore?

$$10FeSO_4 + K_2Mn_2O_8 + 8H_2SO_4 = 5Fe_23SO_4 + K_2SO_4 + 2MnSO_4 + 8H_2O.$$

51. How much potassium dichromate is required to convert one gram of iron from ferrous into ferric salt?

$$K_2Cr_2O_7 + 6FeSO_4 + 7H_2SO_4 = K_2SO_4 + Cr_23SO_4 + 7H_2O + 3Fe_23SO_4.$$

52. A balloon containing 1000 cub. metres is to be filled with hydrogen, when it has gone up to such a height that the pressure is 480 m.m. and the temperature -30° C. How many kilograms of iron must be heated in steam?

$$3Fe + 4H_2O = Fe_3O_4 + 4H_2.$$

53. How much potassium permanganate is required to convert one gram of iron from ferrous to ferric salt?

$$K_2Mn_2O_8 + 10FeSO_4 + 8H_2SO_4 = K_2SO_4 + 2MnSO_4 + 5Fe_23SO_4 + 8H_2O.$$

54. 0·2 gram of levigated iron when dissolved in acid required 30 c.c. of solution of potassium permanganate, containing 3 grams of the salt per litre. What is the percentage of iron?

$$K_2Mn_2O_8 + 10FeSO_4 + 8H_2SO_4 = K_2SO_4 + 2MnSO_4 + 5Fe_23SO_4 + 8H_2O.$$

55. 3 c.c. of a solution of ferrous sulphate required 22·5 c.c. of a solution of potassium dichromate containing 4·9 grams of the salt per litre. How much iron is there in 1 c.c. of the solution?

$$K_2Cr_2O_7 + 6FeSO_4 + 7H_2SO_4$$
$$= K_2SO_4 + Cr_23SO_4 + 3Fe_23SO_4 + 7H_2O.$$

56. How much potassium dichromate must be dissolved in a litre of water, that 1 c.c. of the solution may be equivalent to 0·0056 gram of iron?

$$K_2Cr_2O_7 + 6FeCl_2 + 14HCl$$
$$= 3Fe_2Cl_6 + 2KCl + Cr_2Cl_6 + 7H_2O.$$

57. From how many litres of air at 13° C. is the oxygen removed by a kilogram of iron in rusting?

$$2Fe + 3O = Fe_2O_3.$$

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58. A balloon 100 feet in diameter is to be filled with hydrogen, how many tonnes of iron must be dissolved in acid?

$$Fe + 2HCl = FeCl_2 + H_2.$$

59. What volume of gaseous hydrogen chloride must be dissolved in water to act upon 89 grams of iron? And what volume of chlorine must be passed into the solution to convert the ferrous into ferric salt?

$$Fe + 2HCl = FeCl_2 + H_2.$$
$$2FeCl_2 + Cl_2 = Fe_2Cl_6.$$

60. Calculate the percentage composition of a sample of Swedish steel which gave the following results, (α) 7·791 grams gave 0·208 gram of carbon dioxide, (β) 10·758 grams gave 0·004 gram of barium sulphate, (γ) 10·758 grams gave 0·011 gram of graphite and 0·006 gram of silica, (δ) 10·785 grams gave 0·018 gram of manganoso-manganic oxide.

61. 10 grams of ferrous oxalate when heated in hydrogen gave a mixture of iron and ferrous oxide. The product when dissolved in acid gave 300 c.c. of hydrogen measured over water at 10° C. Find the percentage of iron and of ferrous oxide in the residue.

$$FeC_2O_42H_2O = 2H_2O + CO_2 + CO + FeO.$$
$$FeC_2O_42H_2O = 2H_2O + 2CO_2 + Fe.$$
$$Fe + 2HCl = FeCl_2 + H_2.$$

62. Some steel-grey crystals in a Carinthian blast furnace were found to contain iron 76·23 per cent., and oxygen 23·76 per cent. Find the formula of the oxide.

63. Steam is passed over 9·7 grams of ferrous chloride heated in a tube. What does the resulting hydrogen measure over water at 20° C. and 700 m.m.?

$$3FeCl_2 + 4H_2O = Fe_3O_4 + 6HCl + H_2.$$

64. 1·25 gram of ferric oxide was reduced by hydrogen and the metal dissolved in dilute acid. The hydrogen evolved measured 382·6 c.c. over water at 17° C. and 750 m.m. Find the atomic weight of iron.

$$Fe_2O_3 + 6H = 3H_2O + 2Fe.$$
$$2Fe + 4HCl = 2FeCl_2 + 4H.$$

65. A salt of iron contains iron 43·75 per cent., sulphur 18·75 per cent., and oxygen 37·5 per cent. Find its formula.

66. What volume of sulphur dioxide at 10° C. must be passed into a boiling solution of ferric chloride containing 437 grams of iron to reduce it to ferrous chloride?

$$Fe_2Cl_6 + 2H_2O + SO_2 = 2FeCl_2 + 2HCl + H_2SO_4.$$

CHAPTER XXXII.

COBALT. Co = 59.

NICKEL. Ni = 58.

1. A SUBSTANCE contains cobalt 35·54 per cent., arsenic 45·18 per cent., and sulphur 19·28 per cent. Find its formula.

2. Find the percentage composition of nickelous oxide (NiO).

3. Find the percentage composition of cobaltous sulphate ($CoSO_4 . 7H_2O$).

4. What volume of hydrogen at 15° C. is required to reduce 100 grams of cobaltic oxide?

$$Co_2O_3 + 6H = 3H_2O + 2Co.$$

5. How much nickelic oxide can be obtained by heating 100 grams of nickelous nitrate?

$$2Ni\,(NO_3)_2 6H_2O = 12H_2O + N_2O_3 + Ni_2O_3.$$

6. How much mercuric oxide is required to precipitate 20 grams of nickel as nickelous oxide?

$$NiCl_2 + HgO = HgCl_2 + NiO.$$

7. What volume of hydrogen at 17° C. is required to reduce 10 grams of nickelous oxide?

$$NiO + H_2 = H_2O + Ni.$$

8. Find the percentage composition of potassium and nickel nitrite $NiK_4(NO_2)_6$.

9. What volume of chlorine at 14° C. must be passed into a solution of 1000 grams of cobalt in presence of barium carbonate to precipitate them as cobaltic oxide?

$$2CoCl_2 + 3BaCO_3 + Cl_2 = 3BaCl_2 + 3CO_2 + Co_2O_3.$$

10. What volume of carbon monoxide at 1200° C. is set free in reducing 764 grams of nickelous oxide?

$$NiO + C = CO + Ni.$$

11. Find the percentage composition of potassium cobalticyanide $(K_6Co_2C_{12}N_{12})$.

12. What volume of bromine (Δ 3) is required to precipitate 10 grams of cobalt in presence of barium carbonate as cobaltic oxide?

$$2CoCl_2 + 3BaCO_3 + 2Br = 2BaCl_2 + BaBr_2 + 3CO + Co_2O_3.$$

13. What volume of carbon dioxide at 90° C. is given off on heating 170 grams of nickelous carbonate?

$$NiCO_3 = NiO + CO_2.$$

14. What volume of chlorine at 26° C. and 740 m.m. is evolved on boiling 10 grams of cobaltic oxide with hydrogen chloride?

$$Co_2O_3 + 6HCl = 2CoCl_2 + 3H_2O + 2Cl.$$

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15. Find the formula of Schreibersite containing iron 57·11 per cent., nickel 28·35 per cent., and phosphorus 15·01 per cent.

16. Find the formula of a substance containing hydrogen 3·18 per cent., oxygen 33·88 per cent., nitrogen 14·84 per cent., sulphur 16·95 per cent., and nickel 31·15 per cent.

17. Find the percentage composition of roseo-cobaltic chloride. ($Co_2Cl_6 . 10NH_3 . H_2O$.)

18. 0·7 gram of cobalt gave 292·3 c.c. of hydrogen measured over water at 20° C. and 756 m.m. What is the atomic weight of the metal?

$$Co + 2HCl = CoCl_2 + H_2.$$

19. How many cubic centimetres of nickel (Δ 8·8) will a spherical balloon of gold-beater's skin, 50 c.m. across, weighing 5 grams, and filled with hydrogen just not lift?

20. A substance contains cobalt 26·69 per cent., arsenic 25 per cent., oxygen 21·31 per cent., and water 24 per cent. What is its formula?

21. 1·4 grams of impure cobalt were dissolved in acid and mixed with potassium acetate and nitrate. The precipitate dried at 100° C. weighed 9·2 grams. What percentage of cobalt was there in the substance taken?

$$2CoCl_2 + 2HC_2H_3O_2 + 12KNO_2 + O = 4KCl + H_2O + 2KC_2H_3O_2 + Co_2K_6(NO_2)_{12}.$$

22. If a cubic foot of water weighs 62·4 lbs., find the diameter in inches of a cast-iron (Δ 7·25) 32 lb. cannon-ball.

CHAPTER XXXIII.

CHROMIUM. Cr = 52.

1. FIND the percentage composition of chrome ironstone (Cr_2O_3FeO).

2. How many grams of sodium in vapour must be passed over 147 grams of heated chromic chloride to reduce it to chromium?

$$Cr_2Cl_6 + 6Na = 6NaCl + 2Cr.$$

3. Find the percentage composition of chromic oxide (Cr_2O_3).

4. 10 grams of chromium trioxide when heated left 7·6 grams of chromic oxide. What is the atomic weight of chromium?

$$2CrO_3 = Cr_2O_3 + 3O.$$

5. How much is lost by 100 grams of lead chromate when heated in a stream of hydrogen?

$$2PbCrO_4 + 5H_2 = 2Pb + Cr_2O_3 + 5H_2O.$$

6. According to Berlin 100 parts of lead nitrate give 97·576 parts of lead chromate; find the atomic weight of chromium.

$$Pb2NO_3 + K_2CrO_4 = 2KNO_3 + PbCrO_4.$$

7. 43 grams of chromium trioxide are heated to 250° C. What volume of oxygen at that temperature is evolved?

$$2CrO_3 = Cr_2O_3 + 3O.$$

8. The three most elevated buildings in Europe are (α) the Hospice de St Gotthardt 2075 m., (β) the Hospice de St Bernard 2491 m., (γ) the Observatory on Mount Etna 2942 m. above sea-level. Find each of these altitudes in feet.

9. How many tons of potassium dichromate can be made from 10 tons of chrome ironstone?

$$2FeOCr_2O_3 + 3K_2CO_3 + CaO + 7O = 3K_2CrO_4 + CaCrO_4 + Fe_2O_3 + 3CO_2.$$

$$CaCrO_4 + K_2SO_4 = CaSO_4 + K_2CrO_4.$$

$$4K_2CrO_4 + 2H_2SO_4 = 2K_2SO_4 + 2H_2O + 2K_2Cr_2O_7.$$

10. What is the percentage composition of chromium phosphide (CrP)?

11. 163 grams of chromic oxide are heated with charcoal; how much chromium is formed, and what volume of carbon monoxide at 26° C. is evolved?

$$Cr_2O_3 + 3C = 3CO + 2Cr.$$

12. A substance contains chromic oxide 54·67 per cent., and water 45·33 per cent. Find its formula.

13. What volume of oxygen is given off on heating 2·98 grams of potassium dichromate with hydrogen sulphate?

$$2K_2Cr_2O_7 + 10H_2SO_4 = 4HKSO_4 + 2Cr_23SO_4 + 8H_2O + 6O.$$

14. How many times heavier than air is the vapour of chromium hexafluoride (CrF_6)?

15. Find the percentage composition of potassium chloro-chromate ($KClCrO_3$).

16. What volume of hydrogen at 15° C. is required to reduce 100 grams of chromic to chromous chloride?

$$Cr_2Cl_6 + 2H = 2HCl + 2CrCl_2.$$

17. According to Péligot, 100 grams of chromous chloride ($CrCl_2$) contain 57·5 grams of chlorine. Find the atomic weight of chromium.

18. How much chromic sulphide can be obtained from 100 grams of chromic oxide, and what volume of carbon dioxide at 210° C. is given off?

$$2Cr_2O_3 + 3CS_2 = 2Cr_2S_3 + 3CO_2.$$

19. The vapour of 20 c.c. of chromyl dichloride (Δ 1·7) is passed through a red-hot tube; how much chromic oxide, and what volume of oxygen at 6° C. and of chlorine at 6° C. is evolved?

$$2CrO_2Cl_2 = Cr_2O_3 + 4Cl + O.$$

20. A substance contains potassium 19·84 per cent., chromium 39·57 per cent., and oxygen 40·58 per cent. Find its formula.

21. What volume of sulphur dioxide at 15° C. and 780 m.m. is required to reduce 47 grams of potassium dichromate?

$$K_2Cr_2O_7 + 3SO_2 + H_2SO_4 = K_2SO_4 + Cr_23SO_4 + H_2O.$$

22. A substance contains potassium 27·07 per cent., chromium 12 per cent., carbon 16·62 per cent., and oxygen 44·31 per cent. Find its formula.

23. How much chromyl dichloride can be obtained by distilling 23 grams of sodium chloride with potassium dichromate and hydrogen sulphate?

$$4NaCl + K_2Cr_2O_7 + 3H_2SO_4 = 2Na_2SO_4 + K_2SO_4 + 3H_2O + 2CrO_2Cl_2.$$

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24. How much potassium dichromate must be heated with hydrogen sulphate to make 15 litres of oxygen at 15° C.?

$$K_2Cr_2O_7 + 5H_2SO_4 = 2HKSO_4 + Cr_23SO_4 + 4H_2O + 3O.$$

25. 100 grams of mercurous chromate are heated; how much chromic oxide is formed, and what volume of oxygen is given off?

$$2Hg_2CrO_4 = 4Hg + Cr_2O_3 + 5O.$$

26. What volume of oxygen at 30° C. is given off on heating 70 grams of chromium trioxide?

$$2CrO_3 = Cr_2O_3 + 3O.$$

27. What volume of nitrogen at 150° C. is given off on heating 10 grams of ammonium dichromate?

$$(NH_4)_2 Cr_2O_7 = Cr_2O_3 + 4H_2O + 2N.$$

28. What volume of hydrogen sulphide at 10° C. is required to reduce 100 grams of chromium trioxide?

$$2CrO_3 + 3H_2S = 3H_2O + 3S + Cr_2O_3.$$

29. What volume of chlorine at 30° C. is given off on distilling 1 gram of chromium trioxide with hydrogen chloride?

$$2CrO_3 + 12HCl = 6H_2O + Cr_2Cl_6 + 6Cl.$$

30. 20 grams of potassium dichromate are heated with

hydrogen oxalate and sulphate. What volume of carbon dioxide at 30° C. is given off?

$$K_2Cr_2O_7 + 5H_2SO_4 + 3C_2H_2O_4 = 2HKSO_4 + Cr_23SO_4 + 7H_2O + 6CO_2.$$

31. 21 litres of chlorine at 10° C. are passed over a heated mixture of chromic oxide and charcoal. How much chromic chloride is formed?

$$Cr_2O_3 + 3C + 6Cl = 3CO + Cr_2Cl_6.$$

32. 10 grams of lead chromate are heated with fluorspar and hydrogen sulphate, what volume of chromium hexafluoride at 20° C. is obtained?

$$PbCrO_4 + 3CaF_2 + 4H_2SO_4 = 4H_2O + 3CaSO_4 + PbSO_4 + CrF_6.$$

33. 100 grams of potassium dichromate are boiled with equal quantities of ammonium and sodium nitrates. What volume of nitrogen at 13° C. and 740 m.m. is evolved?

$$K_2Cr_2O_7 + 4NH_4NO_3 + 4NaNO_3 = 5H_2O + 2KNO_3 + 4NaNO_3 + H_6CrO_6 + 4N.$$

34. What volume of nitrogen measured over water at 30° C. and 740 m.m. is evolved on heating 70 grams of ammonium dichromate?

$$(NH_4)_2Cr_2O_7 = Cr_2O_3 + 4H_2O + N_2.$$

CHAPTER XXXIV.

TIN. Sn = 118.

1. **FIND** the percentage composition of tinstone (SnO_2).

2. Find the formula of tin-pyrites which contains copper 29·53 per cent., iron 13·07 per cent., tin 27·53 per cent., and sulphur 29·86 per cent.

3. A sheet of tin-foil (Δ 7·3) is a yard long, a foot wide, and ·01 of an inch thick, find its mass in grams.

4. 100 grams of tin (Δ 7·3) are melted with 100 grams of lead (Δ 11·45). Find the density of the alloy supposing that no change of volume takes place.

5. 10 grams of tin were boiled with hydrogen chloride, when 1·12 litres of hydrogen had been given off the tin was found to weigh 4·1 grams. Find the atomic weight of tin.

$$Sn + 2HCl = SnCl_2 + H_2.$$

6. 100 grams of tin were heated with hydrogen nitrate, after ignition the stannic oxide weighed 127·1 grams. What is the atomic weight of tin?

$$Sn + O_2 = SnO_2.$$

7. What volume of air at 13° C. is required to convert 590 grams of tin into the dioxide?

$$Sn + O_2 = SnO_2.$$

8. 17 grams of tin were dissolved in sodium hydrate, what volume of hydrogen at 15° C. was evolved?

$$Sn + 2HNaO + H_2O = Na_2SnO_3 + 4H.$$

9. The vapour of stannic chloride is 9·199 times heavier than air, and that of stannous chloride 13·08 times heavier. Find the double densities of these vapours referred to hydrogen.

10. What volume of gaseous hydrogen chloride at 60° C. is required to convert 50 grams of tin into stannous chloride?

$$Sn + 2HCl = SnCl_2 + H_2.$$

11. What volume of chlorine at 26° C. is absorbed in converting 1000 grams of tin into the tetrachloride?

$$Sn + 4Cl = SnCl_4.$$

12. 40 grams of bromine are converted into hydrogen bromide which is passed over heated tin; what volume of hydrogen at 15° C. is set free?

$$2HBr + Sn = SnBr_2 + 2H.$$

13. How much "tin-salts" can be made from 488 grams of tin?

$$Sn + 2HCl + 2H_2O = H_2 + SnCl_2 2H_2O.$$

14. Find the percentage composition of stannous metastannate ($SnH_8Sn_5O_{15}$).

15. What volume of hydrogen sulphide at 26° C. is required to precipitate the tin from a solution of 110 grams of "tin-salts"?

$$SnCl_2 2H_2O + H_2S = 2HCl + 2H_2O + SnS.$$

16. A substance contains tin 64·84 per cent., and sulphur 35·16 per cent. Find its formula.

17. What volume of hydrogen at 15° C. is evolved on dissolving 10 grams of tin in hydrogen chloride ?

$$Sn + 2HCl = SnCl_2 + H_2.$$

18. What volume of chlorine at 10° C. must be passed over 80 grams of tin to convert them into stannic chloride.

$$Sn + 4Cl = SnCl_4.$$

19. 40 grams of tin were dissolved in hydrogen chloride, what volume of hydrogen at 39° C. was given off ?

$$Sn + 2HCl = SnCl_2 + H_2.$$

20. Find the formula of a substance containing sodium 16·2 per cent., tin 41·56 per cent., oxygen 16·9 per cent., and water 25·34 per cent.

21. A sheet of iron (Δ 7·8) 1 m. square and 1 m.m. thick is dipped into melted tin. If its original mass be increased by $\frac{1}{40}$, what is the thickness of the layer of tin (Δ 7·3) ?

22. How many grams does a spherical globule of tin (Δ 7·3) 2 m.m. in diameter weigh ?

23. 9 grams of tin are dissolved in aqua regia, what volume of hydrogen sulphide at 15° C. and 770 m.m. is required to precipitate them ?

$$SnCl_4 + 2H_2S = 4HCl + SnS_2.$$

24. 10 c.c. of a solution of stannous chloride, when mixed with excess of ferric chloride, required 47 c.c. of a solution of potassium permanganate containing 3 grams of the salt per litre. How much tin was there in 1 c.c. of the original solution ?

$$SnCl_2 + Fe_2Cl_6 = 2FeCl_2 + SnCl_4.$$

$$K_2Mn_2O_8 + 10FeCl_2 + 16HCl$$
$$= 8H_2O + 5Fe_2Cl_6 + 2KCl + 2MnCl_2.$$

25. Find the formula of a substance containing hydrogen 0·84 per cent., tin 74·06 per cent., and oxygen 25·1 per cent.

26. 4 grams of tin are heated with 200 c.c. of hydrogen sulphide at 10° C. and 740 m.m. How much does the tin increase in mass ?

$$Sn + H_2S = SnS + H_2.$$

27. Find the formula of a substance containing nitrogen 7·63 per cent., hydrogen 2·17 per cent., chlorine 58·03 per cent., and tin 32·16 per cent.

28. A circular sheet of card-board 1 m. across is covered on one side with a sheet of tin-foil (Δ 7·3) 0·02 m.m. thick. By how many grams does the cardboard increase in mass ?

CHAPTER XXXV.

LEAD. Pb = 207.

1. FIND the number of pounds of sheet lead, one square foot of which weighs 5 lbs., on a roof which is 36 feet 9 inches long and 16 feet 8 inches wide.

2. How much litharge can be obtained from 40·5 kilos. of lead, and what volume of oxygen is absorbed in the process?

$$Pb + O = PbO.$$

3. Find the percentage of lead in (α) Anglesite $PbSO_4$, and (β) Cerussite $PbCO_3$.

4. What volume of oxygen is absorbed in converting 37·1 kilos. of lead into litharge?

$$Pb + O = PbO.$$

5. 21·94 grams of litharge gave 20·37 grams of lead, what is the atomic weight of the metal?

$$PbO = Pb + O.$$

6. How many shot 1 m.m. in diameter can be made from 1 000 000 grams of lead (Δ 11·46)?

7. 100 grams of lead (Δ 11·45) are melted with 300 grams of tin (Δ 7·3). If the volume remains unchanged, what is the density of the alloy?

8. How much lead dioxide can be obtained from 20 grams of lead nitrate?

$$Pb2NO_3 + CaOCl_2 + H_2O = 2HCl + Ca2NO_3 + PbO_2.$$

9. Find the percentage composition of lead chromate ($PbCrO_4$).

10. 5 grams of lead chloride gave 5·16 grams of silver chloride, find the atomic weight of lead.

$$PbCl_2 + 2AgNO_3 = Pb2NO_3 + 2AgCl.$$

11. How much lead acetate can be made from 6·69 kilos. of litharge?

$$PbO + 2HC_2H_3O_2 + 2H_2O = Pb\,(C_2H_3O_2)_2 3H_2O.$$

12. Find the percentage of lead in crystallized lead acetate ($Pb\,(C_2H_3O_2)_2 3H_2O$).

13. How much pyroligneous acid containing 40 per cent. of hydrogen acetate is required to form a kilogram of lead acetate?

$$PbO + 2HC_2H_3O_2 + 2H_2O = Pb\,(C_2H_3O_2)_2\,3H_2O.$$

14. Berzelius found that 100 grams of litharge contain 7·1724 grams of oxygen. Find the atomic weight of lead.

$$PbO = Pb + O.$$

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15. If a lead wire $\frac{1}{12}$ inch in diameter will just carry 20 lbs., how many kilos. will a wire 1 m.m. in radius carry?

16. 100 grams of lead nitrate are heated, what volume of nitrogen tetroxide at 150° C. and 730 m.m. is evolved?

$$Pb2NO_3 = PbO + O + 2NO_2.$$

17. Water from a leaden cistern 3 by 2 by 1 metre gave on evaporation with hydrogen sulphate 113 grams of lead sulphate ($PbSO_4$). Find the percentage of lead in the water.

18. 100 grams of white lead boiled with dilute hydrogen nitrate gave 6 litres of carbon dioxide at 15° C. Find the percentage of lead carbonate, lead hydrate and impurities in the white lead.

$$PbH_2O_22PbCO_3 + 6HNO_3 = 3Pb2NO_3 + 4H_2O + 2CO_2.$$

19. Find the formula of a substance containing carbon 7·96 per cent., hydrogen 0·99 per cent., oxygen 10·61 per cent., lead 68·66 per cent., and chlorine 11·79 per cent.

20. 100 grams of lead fluoride are heated with hydrogen sulphate, what volume of hydrogen fluoride at 70° C. and 700 m.m. is given off?

$$PbF_2 + H_2SO_4 = PbSO_4 + 2HF.$$

21. 1000 grams of lead nitrate are heated, how much litharge is left, and what volume of nitrogen tetroxide at 90° C. is given off?

$$Pb2NO_3 = PbO + O + 2NO_2.$$

22. According to Dumas 100 grams of red-lead when heated give 2·4 grams of oxygen. Find the formula of red-lead.

$$(PbO)_n (PbO_2)_m = (PbO)_{m+n} + O_m.$$

23. Find the formula of Cassel yellow which contains lead 90·05 per cent., chlorine 3·86 per cent., and oxygen 6·09 per cent.

24. According to Stas 100 parts of lead form 159·9703 parts of lead nitrate; what is the atomic weight of the metal?

CHAPTER XXXVI.

COPPER. $Cu = 63{\cdot}3$.

1. 1·3305 grams of copper when heated in oxygen gave 1·6675 grams of cupric oxide, find the atomic weight of copper.

$$Cu + O = CuO.$$

2. What volume of hydrogen sulphate (Δ 1·84) and mass of copper are required to yield 30 litres of sulphur dioxide?

$$Cu + 2H_2SO_4 = CuSO_4 + 2H_2O + SO_2.$$

3. Chlorine is passed over 100 grams of copper, how much cupric chloride is formed?

$$Cu + Cl_2 = CuCl_2.$$

4. How much blue vitriol can be obtained from 1000 kilograms of cupric oxide?

$$CuO + H_2SO_4 + 4H_2O = CuSO_45H_2O.$$

5. How many grams of cupric oxide are formed on heating 10 lbs. of copper in air?

$$Cu + O = CuO.$$

6. The vapour of cuprous chloride is 6·93 times as heavy as air, find its double-density referred to hydrogen.

7. 10 litres of air are passed over heated copper, how much cupric oxide is formed?

$$Cu + O = CuO.$$

8. Find the percentage composition of crystallized cupric sulphate ($CuSO_4 . 5H_2O$).

9. 10 litres of hydrogen at 30° C. are passed over hot cupric oxide, how much copper is set free and what volume of steam at 300° C. is formed?

$$CuO + H_2 = Cu + H_2O.$$

10. A substance contains copper 57·5 per cent., carbon 5·4 per cent., hydrogen 0·9 per cent., and oxygen 36·2 per cent.; find its formula.

11. How many kilograms of hydrogen sulphate must be heated with copper to give 300 kilograms of sulphur dioxide, and how much crystallized copper sulphate can be obtained from the solution?

$$Cu + 2H_2SO_4 + 3H_2O = CuSO_45H_2O + SO_2.$$

12. 99 grams of copper are dissolved in hydrogen nitrate, what volume of nitric oxide at 39° C. is formed?

$$3Cu + 8HNO_3 = 3Cu2NO_3 + 4H_2O + 2NO.$$

13. A spiral of copper wire is heated by electricity in a litre of air at 15° C., how much cupric oxide is formed?

$$Cu + O = CuO.$$

14. A current of electricity is passed through acidulated water and through an acidulated solution of cupric sulphate. While 246 c.c. of hydrogen measured over water at 15° C. and 750 m.m. are evolved, how much copper precipitates?

$$H_2O = H_2 + O.$$
$$CuSO_4 + H_2O = Cu + H_2SO_4 + O.$$

15. 3 grams of cuprous hydride are dissolved in hydrogen chloride, what volume of hydrogen at 100° C. and 746 m.m. is evolved?

$$Cu_2H_2 + 2HCl = Cu_2Cl_2 + 2H_2.$$

16. 4·16 grams of cuprous hydride when dissolved in hydrogen chloride gave 1·722 litres of hydrogen at 14° C. and 672 m.m. Find the atomic weight of copper.

$$Cu_2H_2 + 2HCl = Cu_2Cl_2 + 2H_2.$$

17. 7·68 grams of cupric oxide, when heated in hydrogen, left 6·13 grams of the metal. Find the atomic weight of copper.

$$CuO + H_2 = H_2O + Cu.$$

18. 2 grams of cuprous hydride, when dissolved in hydrogen chloride gave 723 c.c. of hydrogen at 10° C. Find the atomic weight of copper.

$$Cu_2H_2 + 2HCl = Cu_2Cl_2 + 2H_2.$$

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19. 40 grams of copper are boiled with hydrogen sulphate; what volume of sulphur dioxide at 100° C. is given off?

$$Cu + 2H_2SO_4 = CuSO_4 + 2H_2O + SO_2.$$

20. 50 grams of copper are dissolved in hydrogen nitrate, what volume of nitric oxide at 200° C. is evolved?

$$3Cu + 8HNO_3 = 3Cu2NO_3 + 4H_2O + 2NO.$$

21. What volume of hydrogen sulphide at 30° C. and 800 m.m. is required to precipitate the copper from a solution of 100 grams of crystallized cupric sulphate?

$$CuSO_45H_2O + H_2S = CuS + H_2SO_4 + 5H_2O.$$

22. 0·5965 gram of cupric sulphate was dissolved in water and mixed with hydrogen sulphite and potassium sulphocyanide. The cuprous sulphocyanide weighed 0·2983 gram. What is the percentage of copper in the sulphate?

$$2CuSO_45H_2O + 2KCNS = 2HKSO_4 + 10H_2O + Cu_2C_2N_2S_2.$$

CHAPTER XXXVII.

MERCURY. $Hg = 200$.

1. **MERCURY-VAPOUR** is 6·976 times as heavy as air, find its double-density referred to hydrogen.

2. 100 volumes of mercury at 0° C. (Δ 13·596) become 102 volumes at 110° C. Find the density of the metal at the higher temperature.

3. What volume of sulphur dioxide is formed on roasting 8000 grams of cinnabar?

$$HgS + O_2 = Hg + SO_2.$$

4. 59·19 grams of mercuric oxide when heated in hydrogen left 54·8 grams of mercury. Find the atomic weight of the metal.

$$HgO + H_2 = H_2O + Hg.$$

5. 1000 c.c. of mercury at 0° C. (Δ 13·596) are cooled to − 40° C.; what is the volume of the solid mercury (Δ 14·39)?

6. Find the percentage composition of turpeth-mineral ($HgSO_4 . 2HgO$).

7. Find the percentage composition of mercuric hydronitrate ($HgHNO_4$).

8. Find the percentage composition of mercuric iodide (HgI_2).

9. 20 grams of sodium amalgam, when placed in water, gave 6·236 litres of hydrogen at 3° C. and 480 m.m. Find the percentage of sodium in the amalgam.

$$Na + H_2O = HNaO + H.$$

10. A kilogram of mercury at 100° C. was mixed with a kilogram of water at 10° C., and the temperature of the mixture was found to be 13° C. What is the specific heat of mercury ?

11. An iron bottle contains 70 lbs. of mercury (Δ 13·56), what is its capacity in litres ?

12. Find the formula of cadmium amalgam containing mercury 78·26 per cent., and cadmium 21·74 per cent.

13. 100 c.c. of mercury (Δ 13·56) are warmed with hydrogen nitrate, what volume of nitric oxide at 26° C. is evolved ?

$$3Hg + 8HNO_3 = 3Hg2NO_3 + 4H_2O + 2NO.$$

14. What volume of mercury (Δ 13·5) and mass of mercuric chloride are required to form 3 kilos. of mercurous chloride ?

$$Hg + HgCl_2 = Hg_2Cl_2.$$

15. The coefficient of expansion of mercury for 1° C. is $\frac{1}{5550}$ of its volume at 0° C. The density of mercury at 0° C. is 13·596, what is the density of the metal at 15° C ?

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16. What volume of cyanogen at 150° C. is given off on heating 100 grams of mercuric cyanide ?

$$HgC_2N_2 = Hg + C_2N_2.$$

17. 70 grams of mercuric oxide are heated, what volume of oxygen at 20° C. and 740 m.m. is given off ?

$$HgO = Hg + O.$$

18. Excess of mercury is heated in 10 litres of air at 14° C., how much mercuric oxide is formed?

$$Hg + O = HgO.$$

19. What volume of hydrogen sulphide at 10° C. and 780 m.m. is required to precipitate the mercury from a solution of 126 grams of mercuric cyanide?

$$HgC_2N_2 + H_2S = HgS + 2HCN.$$

20. How many grams do 500 c.c. of the vapour of mercuric chloride ($HgCl_2$) at 350° C. weigh?

21. A glass bulb weighing 430 grains, when filled with mercury at 0° C. weighs 1510 grains. It is placed in hot oil, and after cooling to 0° C. weighs 1490 grains. If the coefficient of apparent expansion of mercury in glass be $\frac{1}{6480}$, at what temperature Centigrade was the oil?

22. 15 grams of mercury are found to unite with 1·2 grams of oxygen to form mercuric oxide, the molecule of which is believed to consist of one atom of mercury united with one atom of oxygen. One litre of mercury vapour reduced by calculation to 0° C. and 760 m.m. is found to weigh 8·923 grams. What can be deduced from these data about the atomic and molecular weights of mercury?

23. The vapour of mercurous chloride is 8·21 times as heavy as air, what is its apparent molecular weight?

24. One volume of tin (Δ 7·3) combines without change of volume with two volumes of mercury (Δ 13·56). Find the percentage composition and density of the alloy.

25. What column of mercury at 15° C. produces a pressure equal to that of a column of water of 273 m.m. at 20° C.?

CHAPTER XXXVIII.

SILVER. $Ag = 108$.

1. A GRAM of silver (Δ 10·5) can be drawn into a wire 2600 metres in length. Find the diameter of the wire.

2. Find the symbol of Proustite which contains silver 65·45 per cent., sulphur 19·39 per cent., and arsenic 15·16 per cent.

3. Mint silver is an alloy of 7·5 per cent. of copper (Δ 8·9) with 92·5 per cent. of silver (Δ 10·5), and its density is found to be 10·2. What would be the density of the alloy if no change of volume took place, and what do 100 volumes of the two metals occupy after the fusion?

4. How many pounds does a sheet of silver (Δ 10·5) a yard long, a foot wide, and an inch thick weigh?

5. A grain of silver (Δ 10·5) can be drawn into a wire 400 feet long, what is the radius of the wire in millimetres?

6. A shilling weighs 87·27 grains of which 80·727 are silver. How many shillings can be made from a ton of silver and how many grains do they weigh?

7. 10 grams of silver are heated in sulphur vapour, how much silver sulphide is formed?

$$2Ag + S = Ag_2S.$$

8. A gram of silver chloride, when reduced by hydrogen, left 0·7526 gram of the metal. What is the atomic weight of silver?

$$AgCl + H = HCl + Ag.$$

9. Find the percentage composition of silver nitrate ($AgNO_3$).

10. 100 grams of silver combine with 32·86 grams of chlorine. What is the atomic weight of silver?

$$Ag + Cl = AgCl.$$

11. How much silver nitrate can be made from 50 grams of silver?

$$6Ag + 8HNO_3 = 6AgNO_3 + 4H_2O + 2NO.$$

12. An alloy of equal masses of silver (Δ 10·5) and of bismuth (Δ 9·8) is found to have the density 10·709. If no change of volume took place what would the density of the alloy be?

13. Melted silver dissolves 22 times its volume of oxygen at 0° C., what volume of oxygen at 13° C. would be given off from a kilogram of silver (Δ 10·5) on cooling?

14. How many litres of air (containing 20 per cent. by volume of available oxygen) are required to cupel a ton of argentiferous lead containing 320 ozs. of silver?

$$Pb + O = PbO.$$

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15. 105·3 c.c. of hydrogen precipitate 1·01 grams of silver from solution. What is the atomic weight of silver?

$$AgC_2H_3O_2 + H = HC_2H_3O_2 + Ag.$$

16. What volume of oxygen at 30° C. can be obtained by heating 10 grams of argentic oxide?

$$Ag_2O = 2Ag + O.$$

17. What volume of oxygen at 21° C. and 740 m.m. is given off on throwing one gram of silver dioxide into a solution of hydrogen dioxide ?

$$Ag_2O_2 + 2H_2O_2 = 2Ag + 2H_2O + 2O_2.$$

18. A kilogram of silver (Δ 10·512) was found when cold to occlude 174 c.c. of oxygen, what is the percentage of oxygen by mass and by volume ?

19. 100 grams of silver are dissolved in hydrogen nitrate, what volume of nitric oxide at 30° C. and 800 m.m. is given off ?

$$6Ag + 8HNO_3 = 6AgNO_3 + 4H_2O + 2NO.$$

20. Find the percentage composition of silver oxyfluoride (Ag_2HFO).

21. 2 grams of silver dioxide, when heated, give off what volume of oxygen at 110° C ?

$$Ag_2O_2 = Ag_2 + O_2.$$

22. According to Levol an alloy of 71·9 per cent. silver and 28·1 per cent. copper does not separate on cooling. Find its formula.

23. 100 grams of silver chloride absorb 17 grams of ammonia, find a formula for the compound, and calculate from the formula how much chloride is united with 17 grams of ammonia.

24. 10 grams of silver monoxide are exposed to sunshine, what volume of oxygen measured over water at 15° C. and 740 m.m. is evolved; the water column in the tube being 217 m.m. ?

$$Ag_2O = 2Ag + O.$$

CHAPTER XXXIX.

GOLD. Au = 196·6.

1. A SHEET of gold-leaf (Δ 19·3) 0·0001 m.m. thick weighs one gram, what is its area in square centimetres?

2. A wire of gold (Δ 19·3) 3 kilometres in length weighs one gram, find its radius in millimetres.

3. A sovereign weighs 123·274 grains, of which 113·001 are gold. How many sovereigns can be made from a ton of gold, and how many grains do they weigh?

4. 900 grams of gold (Δ 19·3) are fused without permanent change of volume with 100 grams of silver (Δ 10·5). What is the density of the alloy?

5. A nugget of gold (Δ 19·3) was found to weigh 1743 ounces Troy, what was its mass in kilograms and its volume in cubic centimetres?

6. What volume of oxygen is given off on heating 4·412 grams of auric oxide?

$$Au_2O_3 = 2Au + 3O.$$

7. What volume of oxygen is obtained on heating 10 grams of auric oxide?

$$Au_2O_3 = 2Au + 3O.$$

8. Find the percentage composition of auric chloride ($AuCl_3$).

9. 50 grams of auric chloride are heated to 170° C., how much aurous chloride is left and what volume of chlorine at 21° C. is evolved?

$$AuCl_3 = AuCl + 2Cl.$$

10. A solution of 10 grams of auric chloride is mixed with excess of hydrogen oxalate, how much gold is precipitated and what volume of carbon dioxide at 13° C. is given off?

$$2AuCl_3 + 3C_2H_2O_4 = 2Au + 6HCl + 6CO_2.$$

11. Find the percentage composition of ammonium chloraurate ($NH_4AuCl_4 . H_2O$).

12. How much aurous bromide can be made from 2 grams of aurous oxide?

$$Au_2O + 2HBr = H_2O + 2AuBr.$$

13. How much iron can be converted from ferrous to ferric salt by 10 grams of auric chloride?

$$6FeSO_4 + 2AuCl_3 = 2Fe_2 3SO_4 + Fe_2Cl_6 + 2Au.$$

---

14. Find the radius of a gold (Δ 19·3) ball the mass of which is equal to that of a silver (Δ 10·5) ball having a radius of 15 centimetres.

15. The ball at the top of St Paul's is 6 feet in diameter, and covered with gold $\frac{1}{2000}$ of an inch thick. Find the mass of the gold (Δ 19·3) in kilograms.

16. Faraday calculated that the gold (Δ 19·3) in four sovereigns, each containing 113·001 grains, could be made into a wire long enough to go round the earth ($r = 6{\cdot}37 \times 10^6$ metres). Find the radius of such a wire.

17. Equal masses of gold (Δ 19·3) and silver (Δ 10·5) are alloyed without change of volume. Find the density of a liquid in which the alloy will just float.

18. Mint gold is composed of 11 parts of gold alloyed with 1 part of copper. Find an approximate formula for the alloy, and the percentage of gold in a body having that formula.

19. 0·2 gram of auric oxide is thrown into a solution of hydrogen dioxide, what volume of oxygen at 10° C. is evolved?

$$Au_2O_3 + 3H_2O_2 = 2Au + 3H_2O + 3O_2.$$

20. According to Levol, 1000 parts of gold when converted into chloride and exposed to the action of sulphur dioxide, form hydrogen sulphate, which gives 1782 parts of barium sulphate. Find the atomic weight of gold.

$$2AuCl_3 + 3SO_2 + 6H_2O = 2Au + 6HCl + 3H_2SO_4.$$

$$3H_2SO_4 + 3BaCl_2 = 6HCl + 3BaSO_4.$$

21. Prat has described an oxide of gold containing 7·7 per cent. of oxygen, find its formula.

22. A substance contains gold 77·22 per cent., oxygen 9·42 per cent., nitrogen 11 per cent., and hydrogen 2·35 per cent. Find its formula.

CHAPTER XL.

PLATINUM. Pt = 194·9.

1. FIND the percentage composition of (α) potassium K_2PtCl_6, (β) ammonium $(NH_4)_2PtCl_6$ chloroplatinate.

2. 112·3 grams of platinic chloride are heated, what volume of chlorine at 182° C. is given off?

$$PtCl_4 = Pt + 4Cl.$$

3. Find the percentage composition of the green salt of Magnus ($N_2H_6PtCl_2$).

4. 400 grams of ammonium chloroplatinate are heated, how much platinum sponge is left?

$$(NH_4)_2PtCl_6 = Pt + 2HCl + 2NH_3 + 4Cl.$$

5. Find the formula of a substance containing nitrogen 13·83 per cent., hydrogen 2·96 per cent., platinum 48·13 per cent., and chlorine 35·07 per cent.

6. 100 grams of platinum black unite directly with 73·5 grams of arsenic. Find a formula for the alloy, and calculate how much arsenic is required by the formula.

7. 6·981 grams of potassium chloroplatinate lose, according to Berzelius, 2·024 grams of chlorine when heated. Find the *exact* atomic weight of platinum.

$$K_2PtCl_6 = 2KCl + Pt + 4Cl.$$

8. What volume of chlorine at 30° C. can be obtained from 100 grams of platinic chloride?

$$PtCl_4 = Pt + 4Cl.$$

9. How much platinous chloride is required to give 10 litres of chlorine at 350° C.?

$$PtCl_2 = Pt + 2Cl.$$

10. 100 grams of platinum (sp. heat 0·03243) were heated in a furnace and plunged into a vessel of water, weighing when reduced to water 976 grams. The temperature of the water rose from 10° C. to 15° C., what was the temperature of the furnace?

11. How much does a 100-gram weight of platinum (Δ 21·2) lose in air at 15° C.?

12. How many grains of normal air are displaced by (α) the Imperial Standard Pound of Platinum (Δ 21·1572), and by (β) the Quartz Standard Pound (Δ 2·605)?

ANSWERS.

CHAPTER I.

An approximate answer is signified by ?

1. 3000 litres.
2. 2·68 lbs. troy.
3. 9·812 metres.
4. 148 055 600 kiloms.
5. 308 985 kiloms.
6. 344·43 m.
7. 1000 grams.
8. 999·999 grams.
9. 1836 tons.
10. 92 000 000 miles ?
11. 185320″.
    51·47°.
12. 21600 knots.
13. 21564 knots ?
14. $1{\cdot}217289 \times 10^{22}$ cub. ft ?
    $4{\cdot}3 \times 10^{24}$ lbs. ?
15. 0·7034 kilos.
16. 5250 kilos.
17. $1{\cdot}02 \times 10^{12}$ kilos.
18. 1·996 m.
19. 2000·08 grams.
20. 22776·6 kilos.
21. 974·658 c.c.
22. 1400 kilos.
23. 3848 grams.
24. 159·44 tons.
25. 52 360 000 tonnes.
26. 26700 cub. ft.
27. 1·842 density.
28. 5·47723 grams.
29. 423·55 kilogram-metres.
30. 0·909 Δ of turpentine.
    2·295 Δ of copper sulphate.
31. 813·5 c.m.
32. 5·6096 m.

CHAPTER II.

1. (i) 28.
   (ii) 40.
   (iii) 56.
   (iv) 60.
   (v) 102.
2. (i) 57·1 per cent.
   (ii) 40 per cent.
   (iii) 28·5 per cent.
   (iv) 53·6 per cent.
   (v) 47·05 per cent.
3. (i) 30.
   (ii) 40.
   (iii) 160.
   (iv) 100.
   (v) 128.

4. (i) 320.
(ii) 463.
(iii) 233.
(iv) 331.
(v) 212·3.

5. (i) 287.
(ii) 249·3.
(iii) 322.
(iv) 280.
(v) 223.

6. (i) 46.
(ii) 74.
(iii) 60.
(iv) 126.
(v) 140.

7. (i) 92.
(ii) 136.
(iii) 93.
(iv) 284.
(v) 342.

8. (i) 122·6.
(ii) 382.
(iii) 355·6.
(iv) 197.
(v) 294·2.

9. (i) 422·4.
(ii) 182.
(iii) 248.
(iv) 209.
(v) 628.

CHAPTER III.

1. (i) 45° C.
(ii) 35° C.
(iii) 95° C.
(iv) 75° C.
(v) 65° C.

2. (i) 72° R.
(ii) 12° R.
(iii) 16° R.
(iv) 44° R.
(v) 24° R.

3. (i) 158° F.
(ii) 168° F.
(iii) 126° F.
(iv) 17° F.
(v) −25° F.

4. (i) 7·1° R.
(ii) 43·1° R.
(iii) 60·4° R.
(iv) 79·1° R.
(v) −27·5° R.

5. (i) 141° F.
(ii) 104° F.
(iii) 158° F.
(iv) 23° F.
(v) −34° F.

6. (i) 97·2° C.
(ii) 82·2° C.
(iii) 45·5° C.
(iv) −17·7° C.
(v) −34·4° C.

7. (i) 1189·4° F.
(ii) 1328° F.
(iii) 1580° F.
(iv) 1783·4° F.
(v) 1832° F.

8. (i) 356·66° C.
(ii) 37·78° C.
(iii) 239·44° C.
(iv) 1914·45° C.
(v) 1616·11° C.

9. (i) 279°.
(ii) 353°.
(iii) 232°.
(iv) 259°.
(v) 173°.

10. (i) 294·1°.
(ii) 253°.
(iii) 318°.
(iv) 1384·1°.
(v) 234·67°.

11. (i) 27° C. 21·6° R. 80·6° F.
(ii) 127° C. 101·6° R. 260·6° F.
(iii) 227° C. 181·6° R. 440·6° F.

12. 42° F. = 5·$\dot{5}$° C. = 4·$\dot{4}$° R.
− 32° F. = − 35·$\dot{5}$° C. = − 28·4° R.
327° R. = 408·75° C. = 767·75° F.
− 2° R. = − 2·5° C. = 27·5° F.
78° C. = 62·4° R. = 172·4° F.
− 172° C. = − 137·4° R. = − 277·6° F.

CHAPTER IV.

1. 1142·85 c.c.
2. 1388·$\dot{8}$ c.c.
3. 82·64 c.c.
4. 1181·$\dot{8}\dot{1}$ c.c.
5. 258·14 c.c.
6. 100·03 lit.
7. 1097·56 c.c.
8. 791·$\dot{6}$ c.c.
9. 183·63 lit. ?
10. 52·47 c.c.
11. 140·25° C.
12. 1500 c.c.
13. 300 c.c.
14. 142·029 c.c.
15. 760 c.c.
16. 300 c.c.
17. 1111 c.c.
18. 1000 c.c.
19. 651·057 c.c.
20. 1333·$\dot{3}$ c.c.
21. 213 lit.
22. 1096·509 c.c.
23. 265·8° C.
24. 902 m.m.
25. 4689° C.
26. 1230·47 c.c.
27. 1000 c.c.
28. 209·1 lit.
29. 894·51 c.c.
30. 59·92 c.c.
31. 1895·604 c.c.
32. 10 c.c.

CHAPTER V.

OXYGEN.

Answers followed by ! *are obtained by using* 22·32 *litres as two volumes, and* ·00367 *as the coefficient of expansion of a gas.* ? *after answers means nearly.*

1. 19·59 grams.
2. 14 litres.
3. 408·$\dot{3}$ grams.
4. (*a*) 1·716 lit. (β) 2·574 lit.
5. 64 grams.
6. 116·51 grams.
7. 20·4 grams.
8. 5·185 litres.

9. 490 grams chlorate.
   192 grams oxygen?
10. 255·4 grams.
11. 590·287 lit.
12. 17·78 grams oxygen.
    145·018 grams dioxide.
13. 14·93 lit.
14. 177·67 grams chlorate.
15. 8·29 lit.
16. 27·406 lit.
17. 92·7 c.c.
18. 1·177 lit.
19. 14 litres normal.
    16·146 lit.
20. 253·68 c.c.
21. 269·6 c.c.
22. 17·85 grams!
23. O = 15·959?
24. 1·221 lit!
25. 150·1 c.c!
26. 0·716 gram!

CHAPTER VI.

HYDROGEN.

1. 34·3558 lit.
2. 50·3675 grams.
3. 132·1 lit.
4. 14·93 lit.
5. 101·74 grams.
6. (α) 1054·9 c.c.
   (β) 1366·3 c.c.
   (γ) 2098·5 c.c.
7. (α) 731·9 c.c.
   (β) 678·55 c.c.
   (γ) 597·85 c.c.
8. 2·856 grams.
9. 39·1515 grains.
10. 0·0265 grain.
11. 42·19 lit.
12. 333·18 c.c.
13. 3·7935 grams.
14. (α) 2·74 per cent.
    (β) 5·88 per cent.
    (γ) 17·64 per cent.
15. 2929·09 lbs. hydrogen.
    42284·3 lbs. air.
16. 199·6 c.c.
17. 230·1 grams!
18. (α) 29·33 c.c.!
    (β) 19·19 c.c.!
    (γ) 15·27 c.c.!
19. 26·92 lit.!
20. 75·17 lbs. per 1000 cub. ft.!
21. 0·0695 gram!
22. 26·5 atmos.!
23. 13·44 kilos!
24. (α) 0·089568 gram. (β) 0·0895917 gram. (γ) 0·090086 gram.
    Mean. 0·0896559 gram.

CHAPTER VII.

WATER.

1. 12·$\dot{4}$ lit. hydrogen.
   6·$\dot{2}$ lit. oxygen.
2. ·0000896.
3. 261·205 lit.
4. 67·132 lit.
5. 182·44 grams.
6. 6·48 lit. ?
7. (α) 974·5 c.c.
   (β) 1082·2 c.c.
8. $3{\cdot}694 \times 10^{10}$ kilos.
9. 34·9 cub. feet ?
10. 21781·2 grams at 26·4° C.
11. nil.
12. 0·494 gram.
13. 2·546 lit.
14. 304·3 lit.
15. 1087 c.c. ?
16. 258 600 cub. met.
17. 0·296.
18. 2612 times ?
19. 206·9592 m. long.
    24·9936 m. broad.
    18·288 m. deep.
20. 136·2 lit.
21. 8.
22. 12·5.
23. 12·1 kilos.
24. 6·53 c.c.
25. 1 000 427 c.c.
26. 88·897 per cent. oxygen.
    11·102 per cent. hydrogen.
27. 2·72 cub. ft. sat.
    (2·476 Rankine).
    33·82 cub. ft. unsat.
28. 54·67 lit.
29. (i) 62·93 grams.
    (ii) 57·6 grams.
    (iii) 45·91 grams.
    (iv) 14·51 grams.
30. 202·3 c.c.
31. 479·3 times.
32. 4·17 vols. dioxide.
    95·83 vols. water.
33. 3·402 lit. !
34. 14·3 per cent. !

CHAPTER VIII.

NITROGEN.

1. 125 grams.
2. 209·2 lit.
3. 3·5 lit.
4. 40·96 lit.

5. 5 per cent. hydrogen.
35 per cent. nitrogen.
60 per cent. oxygen.

6. 6·$\dot{6}$ litres.

7. 67·2 lit.

8. 296·4 lbs.

9. 2·353 lit.

10. 6·18 lit.

11. 42·38 grams.

12. 142·85 grams.

13. 23·55 c.c.
0·0294 gram.

14. 23·93 lit.

15. 626·6 c.c. sulphate.
494·1 c.c. nitrate.

16. (α) 196·43 grams?
(β) 339·28 grams.

17. 17·$\dot{7}$ lit.

18. 0·3234 grams.

19. 2·106 grams.

20. 4·668 litres.

21. 10·472 lit.

22. 76·51 at 27° C.
45·3 at 180° C.

23. (α) Nitrogen 21·37 per cent.
Oxygen 24·43 per cent.
Chlorine 54·2 per cent.
(β) Nitrogen 17·17 per cent.
Oxygen 39·26 per cent.
Chlorine 43·55 per cent.

24. 4·37 lit.

25. 2·41 lit.

26. 1·12 lit. dioxide.
2·24 lit. nitrogen.

27. 55·47 lit.

28. 11·79 lit. nitrogen.
17·69 lit. dioxide.

29. Ag NO.

30. 6·13 lit.

31. 97·08 lit.

32. 1·76 kilos.

33. 131·77 lit.

34. 14·5 c.c. nitrogen.
8·25 c.c. oxygen.

35. 2·818 grams.
604·25 c.c. hydrogen.

36. 14·8 per cent.?

37. 28·73 lit.!

38. 100·01 lit.

39. 86·72 lit.!

40. 12·7232 grams!
10·367 lit.!

41. 9·175 grams!

42. Nitrogen 2·58 per cent.
Mercury 73·95 per cent.
Iodine 23·47 per cent.

CHAPTER IX.

The Atmosphere.

1. 53·6 c.c.
2. 1586·6̇ c.c.
3. 598·4311 kilos.
4. 0·2582 grams.
5. 78·15 tons.
6. 1 553 328 600 cub. m.
7. 181·4 c.c.
8. 219·3 lit.
9. 15·82 c.c. nitrogen.
   21·64 c.c. hydrogen.
10. (α) 27260 grams.
    (β) 10·31 tons.
    (γ) 95·333 feet.
11. 754·59 lbs. air.
    179·568 lbs. oxygen.
12. 89·7 kilos.
13. 54·091 kilom. radius.
14. 4·4384 grams.
    19·067 litres.
15. 1066·6̇ lit.
16. 0·31 grams.
17. 5·45 grams.
18. 92·333 litres.
19. 2·0246 grams.
20. 665 grams.
21. Oxygen 23 per cent. by mass, 20·72 per cent. by vol.
    Nitrogen 77 per cent. by mass, 79·28 per cent. by vol.
22. 21·358 grams?
23. 101·18 tons?
24. 29·739 grams!
25. 1·422 c.m.!
26. 199·7 tons.
27. 590·97 m.m.
    2158 m.
28. Nitrogen 79·1 per cent.!
    Oxygen 19·27 per cent.!
    Carbon dioxide 1·629 per cent.!
29. 133·6 c.c.!
30. 18·6° C. 70·32 grams.

CHAPTER X.

Carbon.

1. 2 c.c.
2. (α) 28·56 cubic feet.
   (β) 2117·8 lbs.?
3. 1111·1̇.
4. 32·3.
5. 116·46 grams.
6. 126·65 grams.
7. 4·756 lit. dioxide.
   2·547 grams carbon.
8. (α) 80 lit.
   (β) 50·9 lit.
9. 20 c.c. oxygen.
10. 20 c.c. monoxide.
    35 c.c. oxygen.
11. 11·513 grams.
12. COS.

13. $13{\cdot}0\dot{6}$ lit.
14. 16·47 lit.
15. 9·739 lit.
16. 31·2 lbs. dioxide.
13·4 lbs. water.
17. 43·105 grams.
18. − 83·7° C.
19. 81·558 grams.
20. 4·468 grams.
21. 5 892 000 kilos.
22. 1648·32 metres.
23. 255·3° C.
162·2 grams carbon to melt ice.
232·29 grams of carbon to heat mercury.
24. 2·507 ozs. carbonate.
4·47 ozs. tartrate.
25. 1·301 lit.
26. 7·14 grams.
27. 15·62 lit.
28. Carbon (α) 75, (β) 85·71, (γ) 92·3.
Hydrogen (α) 25, (β) 14·29, (γ) 7·7.
29. 59·946 grams.
30. 100 c.c.
31. 50 c.c. dioxide.
25 c.c. oxygen.
32. (α) 1·16 grams.
(β) 1·25 grams.
33. Potassium 60·06 per cent.
Carbon 18·43 per cent.
Nitrogen 21·5 per cent.
34. 46·43 grams.
35. 69·8 c.c.
36. 48·75 grams.
37. 3·168 grams.
38. 3·4125 grams.
39. 45·05 lit.
40. 28·5 per cent. water.
41. 20 lit. !
42. 379·95 grams !
43. 102·2 !
44. $C_7H_{10}O_4$ methyl. citraconate.
45. 110·9 !
46. 42·9 !
47. 153·4.
48. 11·31 grams !
49. 22·5 !
50. CH_2O.
51. C_8H_{12}.
52. $C_{17}H_{24}O_3$.
53. $C_2O_3H_2O$ hydrogen oxalate.
54. $C_6H_{14}O_6$ mannite.
55. $C_7H_6O_2$ hydrogen benzoate.
56. $C_{13}H_{20}N_4O_5$ gelatin.
57. $C_8H_{10}N_4O_2$ theine.
58. $C_5H_4N_4O_3$ hydrogen urate.
59. Carbon 39·08 per cent.
Hydrogen 2·18 per cent.
Nitrogen 15·23 per cent.
Oxygen 43·51 per cent.
$C_6H_4N_2O_5$.
60. $C_7H_6O_2$ hydrogen benzoate.
61. $C_2H_5HSO_4$ ethyl and hydrogen sulphate.
62. C_5H_7N.
63. Carbon 34·02 per cent.
Hydrogen 6·19 per cent.
Iodine 59·87 per cent.
Iodohexane $C_6H_{13}I$.

CHAPTER XI.

Chlorine.

1. 56 lit.
2. 146·25 grams.
3. 396·5 lit.
4. 136·81 grams.
5. 0·391 grams.
6. 75·7 lbs.
7. 201·57 lit.
8. 62·4 grams.
9. 1603 grams.
10. 5·762 per cent. real acid.
11. 316 c.c.
12. 47·87 lit.
13. 304·2 lbs.
14. 134·3 lit.
15. 71·3 lit.
16. 22·4 lit. oxygen.
    168·6 grams perchlorate.
17. 742·8̇ lit.
18. 99·31 kilos.
19. 43·76 lit.
20.

	(α)	(β)	(γ)
Calcium	27·97	31·5	32·97
Chlorine	49·66	55·9	39·01
Oxygen	22·37	12·6	26·37
Hydrogen			1·65

21. 59·5 for Cl_2O_3.
    67·5 for Cl_2O_4.
22. 124·4 grams.
23. 3·088 grams.
24. 6·2 grams.
25. 236 lit. !
26. 2·594 lit. !
27. 176·65 lit. !
28. 6·28 lit. chlorine ? !
29. 3·784 lit. !
30. 777·7 c.c. !
31. 396·5 lit. !
32. 102·3 c.c. !
33. 4.444 lit. !
34. 1·841 lit. !
35. 93·4 per cent. !
36. 50·19 per cent. !
37. 15·12 lit. !
38. 32·71 grams !

CHAPTER XII.

Bromine.

1. 492·9 cub. m.
2. 333·3̇ c.c.
3. 0·00717 gram.
4. 360 c.m.
5. 47·06 per cent. bromine.
   52·94 per cent. water.
6. 14·9 grams ?
7. 3·57 grams.
8. (α) 645·1 grams bromide.
   (β) 181·02 grams bromate.
9. 0·4599 grams.
10. 2·478 lit.

11. 10·338 lit.
12. 748·15 grams.
13. 57·44 per cent. silver.
42·55 per cent. bromine.
14. 2·106 lit.
15. 80·84.
16. 220 c.c.
17. 0·004624 gram !
18. 20·81 grams.
19. 4·017 grams phosphorus.
11·9 c.c. bromine.
20. Br = 80·036.
21. 1·996 m.m.

CHAPTER XIII.

Iodine.

1. 380·67 kilos.
2. 993·6.
3. 251·6.
4. 672 c.c.
5. (α) 0·04465 gram.
(β) 0·04465 gram.
6. 1·86 lit.
7. 877·09 grams.
8. 37·787 grams iodine.
1·874 ,, phosphorus.
20·082 ,, iodide.

9.

	(α)	(β)
Iodine	76·05	69·4.
Oxygen	23·95	30·6.

10.

	(α)	(β)
Hydrogen	0·57	0·52.
Iodine	72·2	66·14.
Oxygen	27·23	33·34.

11. 52·47 lit.
12. 2·3017 lit.
13. 40·62 grams phosphorus !
499·1 grams iodine !
14. 53·17 grams !
15. 0·259 gram ?
16. 2·378 grams iodine.
2·978 grams bromine.
1·032 grams chlorine.
17. Carbon 3·046 per cent.
Hydrogen 0·254 per cent.
Iodine 96·7 per cent.

CHAPTER XIV.

Fluorine.

1. 51·3 grams ?
2. 174·36 grams.
3. 4·62 lit.
4. 60 grams silica.
288 grams fluosilicate.

5. 18·96.

6. (α) Calcium 51·28 per cent.
Fluorine 48·72 per cent.
(β) Sodium 32·85 per cent.
Aluminium 12·85 per cent.
Fluorine 54·3 per cent.

7. 19·002.

8. 13·69 lit.

9. 28·71 lit.

10. 0·281 gram.

11. 7·86 grams !

12. 42·48 lit. !

13. 19·6 !

14. Ans. 11 is doubled.
Ans. 12 is halved.

CHAPTER XV.

SULPHUR.

1. (α) Lead 86·6 per cent.
Sulphur 13·4 per cent.
(β) Zinc 67 per cent.
Sulphur 33 per cent.

2. (α) $CuFeS_2$.
(β) $CaSO_4$.

3. (α) 487·8 dm cubed.
(β) 511 dm cubed ?

4. 5·6 lit.

5. 14 lit.

6. 6·72 lit.

7. 6·72 lit.

8. 14·285 grams.

9. 11·04 tonnes.

10. 313·7 grams.

11.

	(α)	(β)
Hydrogen	2·39	2·04 per cent.
Sulphur	39·02	32·65 per cent.
Oxygen	58·59	65·31 per cent.

12. 13·02 tonnes.

13. 2·828 lit.

14. 2·5194 lit.

15. 71·7 lit.

16. 1·184 grams.

17. 49.

18. 26·97 grams.

19. 3062·5 grams sulphate.
989·06 grams copper.

20. 15·54 lit.

21. 26·51 grams.

22. 28·76 lit.

23. A room of 538·2 cub. m. or 8·135 m. each way.

24. 10·82 lit.

25. 32·0004.

26. 64.

27. $H_2S_2O_7$ Nordhausen hydrogen sulphate.

28. 296·47 lit.

29. $1{\cdot}6\dot{3}$ tons.

30. 24·15 grams.

31. 54·422 tons.

32. 98·1515.

33. 459·375 kilos.
34. 887·68 lit.
35. 600·7 grams.
36. 5·204 lit.
37. 368·48 grams.
38. 13·63 grams.

39. (α)
Potassium 44·9 per cent.
Sulphur 18·37 per cent.
Oxygen 36·73 per cent.
(β)
Sodium 32·39 per cent.
Sulphur 22·54 per cent.
Oxygen 45·07 per cent.

40. (α)
Iron 20·15 per cent.
Sulphur 11·51 per cent.
Oxygen 23·02 per cent.
Water 45·32 per cent.
(β)
Potassium 8·25 per cent.
Aluminium 5·69 per cent.
Sulphur 13·5 per cent.
Oxygen 27 per cent.
Water 45·56 per cent.

41. 392·85 grams.
42. 9·704 lit.
43. 6·99 lit. sulphur vapour.
9·32 lit. steam.
44. 2·94 lit.
45. 7·18 lit.
46. 2·54 lit.
47. 86·57 lit.
48. 0·857 gram.
49. 2·513 kilos.
50. 5·214 lit.
51. Sodium 18·54 per cent.
Sulphur 25·81 per cent.
Oxygen 19·36 per cent.
Water 36·29 per cent.
52. 44·318 lit.
53. 3338·5 lit. !
54. 2·219 lit. !
55. 1·177 !
56. 9·71 grams !
57. 1170 lit. !
58. 11·23 lit. !
59. 17·625 lit. !
60. 28·165 lit. !
61. 18·91 lit. !
62. 12·495 c.c. !
63. 11·77 lit. ! ?
64. 33·728 grams ! ?
65. 612·1 kilos. pyrites.
2155 cub. m. air !
478·5 cub. m. steam !

CHAPTER XVI.

BORON.

1. (α) B_2O_3.
(β) SiO_2.
2. Sodium 12·04 per cent.
Boron 11·52 per cent.
Oxygen 29·32 per cent.
Water 47·12 per cent.
3. 117·5.
4. 441·6 lit.

5. 4·72 lit.
6. 6·57 lit.
7. 6·13 lit.
8. $H_6B_4O_9$ at 100° C.
$H_2B_4O_7$ at 160° C.
9. Boron 6·01 per cent.
Chlorine 77·59 per cent.
Nitrogen 7·65 per cent.
Oxygen 8·74 per cent.
10. 18·11 lit.!
11. 3·388 grams!
12. $3NH_3 . 2BCl_3$.
13. 21·03 lit.!

CHAPTER XVII.

SILICON.

1. 15·13 grams.
2. Barium 49·11 per cent.
Silicon 10·04 per cent.
Fluorine 40·85 per cent.
3. 1·75 grams.
4. Zinc 58·56 per cent.
Silicon 12·61 per cent.
Oxygen 28·83 per cent.
5. 3·9$\dot{1}$ lit.
6. 1·36 grams.
7. 28·86 lit.
8. 224 lit. monoxide.
850 grams tetrachloride.
9. 30·$\dot{6}$ grams sulphide.
7·8$\dot{2}$ lit. dioxide.
10. 5·374 grams.
11. Magnesium 19·05 per cent.
Silicon 29·63 per cent.
Oxygen 46·56 per cent.
Water 4·76 per cent.
12. $MgCaSi_2O_6$.
13. 1387·55 grams.
14. $CaSiO_3$.
15. $Al_2SiO_5 . 5H_2O$.
16. 54·46 lit.!
17. 4·84 grams!
18. $(CaO)_2(Na_2O)(Al_2O_3)_3(SiO_2)_9(H_2O)_9$.
19. $FeMg_3Ca_4Si_8O_{23}$.
20. 3·65 grams!
21. 171·5 for $SiCl_4$.
104 for SiF_4.
22. 27·22 lit.!
23. 4·39 grams!
24. $Mg_2Si_2O_6 . H_2O$.
25. $(Al_2O_3)_3(SiO_2)_3F_2$.
26. $(Na_2O)(CaO)_3(Al_2O_3)_4(SiO_2)_9(H_2O)_9$.
27. $([FeMg]O)_4(Al_2O_3)_4(SiO_2)_{10}H_2O$.
28. $[K_2CaNa_2]O[Al_2Fe_2]O_3 . 6SiO_2$.
29. 27·85 if $Ag = 108$ and $Cl = 35·5$.
30. Silicon 17·07 per cent.
Oxygen 29·27 per cent.
Carbon 43·9 per cent.
Hydrogen 9·7$\dot{6}$ per cent.

CHAPTER XVIII.

PHOSPHORUS.

1. 1·86 kilos.
2. 140 grams.
3. 21·24 kilos.
4. 2·784 lbs.
5. 57·49 grams.
6. 85·5 lit.
7. 31·1.
8. 6·83 grams.
9. 18·1506 tons.
10. 127·6.
11. 21.
12. 25·92 grams.
13. 20·46 grams.
14. 1068·4 lit.
15. 304·5 kilos.
16. 3173·5 kilos.
17. (α) 71·11 grams.
    (β) 47·4 grams.
    (γ) 23·7 grams.
18. (α) 180·76 grams.
    (β) 71·7 grams.
19. 5677·67 grams.
20. $Ca_3P_2O_8$.

		(α)	(β)	(γ)
21.	Silver	77·33 per cent.	71·28 per cent.	57·76 per cent.
	Phosphorus	7·4 per cent.	10·26 per cent.	16·58 per cent.
	Oxygen	15·27 per cent.	18·48 per cent.	25·66 per cent.

22. Magnesium 21·62 per cent.
    Phosphorus 27·93 per cent.
    Oxygen 50·45 per cent.
23. Sodium 12·85 per cent.
    Hydrogen 0·28 per cent.
    Phosphorus 8·66 per cent.
    Oxygen 17·87 per cent.
    Water 60·33 per cent.
24. Sodium 11·00 per cent.
    Nitrogen 6·7 per cent.
    Hydrogen 2·39 per cent.
    Phosphorus 14·89 per cent.
    Oxygen 30·62 per cent.
    Water 34·4 per cent.
25. 5·395 lit.
26. 42·58 grams hypophosphite.
    3·61 lit. phosphine.
27. 15·18 grams.
28. 13·2 grams.
29. P_2H.
30. 31.
31. 153.
32. 358. c.c. oxygen.
33. 34·2.
34. 137 ?
35. 180·64 lit.
36. 4·929 lit.
37. 32·65 grams.
38. 2·42 lit.
39. 1584·84 c.c.
40. 604·31 grams.
41. $P_2O_3Cl_4$.
42. 42·33 lit. !

43. 8·678 lit. !

44. 8·425 lit. !

45. $H_4P_2O_7$ or
$H_{10}P_4O_{15}$ or
$H_{17}P_7O_{26}$.

46. 113·9 lit. !

47. 169·3 lit. !

48. 958·19 grams.

49. Sodium 29·36 per cent.
Phosphorus 26·38 per cent.
Oxygen 44·26 per cent.

50. $([MgFe]O)_6(P_2O_5)_5(Al_2O_3)_5(H_2O)_5$.

51. 287·25 lit. !

52. 5·309 grams !

53. 1·11 lit. !

54. 141·4 lit. ! ?

55. 949 c.c. !

56. 9·17 lit. ? !

57. (α) 28·49 lit. !
(β) 26·26 lit. !
(γ) 26·77 lit. !

58. 11·88 lit. !

59. 17·485 litres !

60. 4·553 litres !

61. 5050° C.

62. 1026·2° C.

CHAPTER XIX.

Arsenic.

1. 12·19 grams ?

2. 4·708 grams.

3. Silver 65·45 per cent.
Arsenic 15·15 per cent.
Sulphur 19·4 per cent.

4. 542 c.c.

5. 124 grams orpiment.
16·97 lit. dioxide.

6. 9·4413 grains.

7. 9·6969 lit.

8. 0.2275 grams.

9. 156·16 grains.

10. 399.

11. 13·97 grams.

12. 8·705 grams.

13. Copper 33·8 per cent.
Hydrogen 0·53 per cent.
Arsenic 40·05 per cent.
Oxygen 25·62 per cent.

14. 3·482 grams.

15. 230 c.c.

16. 0·627 lit. !

17. 733·5 c.c. !

18. Copper 24·99 per cent.
Arsenic 44·42 per cent.
Carbon 4·74 per cent.
Hydrogen 0·59 per cent.
Oxygen 25·26 per cent.

19. 36·3 lit. !

20. 8·24 grams !

21.

	(α)	(β)	(γ)
Arsenic	70·1	61	48·4 per cent.
Sulphur	29·9	39	51·6 per cent.

22. 74·91.

CHAPTER XX.

ANTIMONY AND BISMUTH.

1. 728·6 kilos ?
2. 134 grams.
3. (α) 17·24 c.c.
   (β) 14·71 c.c.
   (γ) 10·1 c.c.
4. 9·935.
5. 146·25 grams.
6. 9·007 lit.
7. 0·667 grams.
8. Sb = 120·009.
9. 20 lit.
10. 104·1 grams.
11. 507·2° F. 211·2° R.

		(α)	(β)	(γ)	(δ)
12.	Bismuth	92·93	89·74	86·8	84 per cent.
	Oxygen	7·07	10·26	13·2	16 per cent.

13. 2·506 lit.
14. 9·664.
15. 9·0879.
16. (α) 8. (β) $11\cdot\dot{3}$. (γ) 26. (δ) 41 grams.
17. $46\cdot\dot{6}$ lit.
18. 2·88 lit. !
19. 1064·5 lit. !
20. 59·016 grams !
21. 46·428 grams !
22. 469·9 c.c.
23. Bismuth 42·98 per cent.
    Nitrogen 8·68 per cent.
    Oxygen 29·74 per cent.
    Water 18·6 per cent.
24. Carbon 14·5 per cent.
    Hydrogen 1·2 per cent.
    Potassium 11·8 per cent.
    Antimony 36·1 per cent.
    Oxygen 33·7 per cent.
    Water 2·7 per cent.
25. 207·996.

CHAPTER XXI.

THE GENERAL PROPERTIES OF THE METALS AND ALLOYS.

1. (α) 5·18 c.c. gold.
   (β) 8·77 c.c. lead.
   (γ) 102·7 c.c. sodium.
2. (α) 4·65 c.c. platinum.
   (β) 9·52 c.c. silver.
   (γ) 57·48 c.c. magnesium.
3. 318·35 m.
4. 0·000127 m.m.
5. 981·5 kilos.
6. 281·5 c.c.
7. 5*s.* 3½*d.*
8. 18·32 c.m.
9. 974·28 grams.
10. 6400·3 tons ?
11. 44·45 tons.
12. 387·2 kilos.
13. 46·048 m.
    3·17*d.* per foot.
14. 68·93 c.m.

15. 79·248 grams.
16. 0·4223 grams.
17. 100 kilos. copper.
    12 kilos. tin.
18. 27901·7 times.
19. 5·3324 c.m.
20. 4 m.m. for iron.
    3·266 m.m. for nickel.
    2·89 m.m. for cobalt.
21. 3·76 m.m.
22. 2·08 c.m.
23. 0·000154 gram.
24. 32 617 728 tons.
25. 25 529 tons.
26. 8·7.
27. 7·24.
28. 35 volumes.

CHAPTER XXII.

POTASSIUM.

1. 3·602 grams.
2. (α) 1·427 lit. for K_2O.
   (β) 2·854 lit. for K_2O_2.
   (γ) 4·281 lit. for K_2O_3.
   (δ) 5·708 lit. for K_2O_4.
3.

(α)	(β)	(γ)
H 1·78	K 38·68	K 31·9
K 69·7	N 13·85	Cl 28·95
O 28·52	O 47·47	O 39·15.

4. 229·156 lit.
5. 25·39.
6. 135·6 c.c.
7. (α) 1231·7 grams carbonate.
   (β) 659·5 grams hydrate.
8. 17·2788 grams.
9. 1463·1 kilos nitrate.
10. 2·475 lit.
11. 76 lit.
12. 1·0656 lit.
13. $KClO_4$.
14. 12·66 lit.
15. 0·27 grams.
16. K_2H.
17. 10·68 grams evolved.
    118·4 c.c. oxygen.
    473·6 c.c. nitrogen tetroxide.
18. Potassium 35·52 per cent.
    Silicon 12·72 per cent.
    Fluorine 51·76 per cent.
19. 6·55 atmospheres.
20. (α) 33·16 litres at 0° C.
    (β) 154·62 litres at 100° C.
21. 5·126 lit.
22. 6·02 lit. !
23. 1·609 lit. !
24. 41·18 lit. !
25. Potassium 14·06 per cent.
    Aluminium 9·71 per cent.
    Silicon 30·2 per cent.
    Oxygen 40·01 per cent.

CHAPTER XXIII.

Sodium.

1.

	(α)	(β)
Sodium	43·4	16·08 per cent.
Carbon	11·32	4·19 per cent.
Oxygen	45·28	16·78 per cent.
Water		62·93 per cent.

2. 9·7 grams.

3. 84·25 lit.

4. 8·68 kilos. sodium.
12·698 cub. met. dioxide.

5. 433·96 grams.

6. Sodium 39·32 per cent.
Chlorine 60·68 per cent.

7. Na = 23.

8. 1·325 kilos. carbonate.
0·925 kilo. lime.

9. 411·9 lbs.

10. 453 kilos. ?

11. 121·3 grams sulphate.
88·29 lit. chloride.

12. 95·74 per cent.

13. 44·1 per cent. sulphate.
55·9 per cent. water.

14. 1·85 lit.

15. 54·93 grams sulphide.
66·56 lit. monoxide.

16. 1213·6 kilos. salt cake.
382·9 c. met. chloride.

17. 2519·9 kilos. crystals.
965·217 kilos. hydrochloric acid.

18. 1·076 lit.

19. 2·714 c.m.

20. 0·625.

21. (α) 4·16 per cent.
(β) 1·85 per cent.

22. 32·03 per cent. potassium.
18·83 per cent. sodium.
49·14 per cent. CO_2.

23. 1000 lit. !

24. (α) 494 c.c. !
(β) 988 c.c. !

CHAPTER XXIV.

Ammonium.

1. NH_4Cl.

2. 4072·365 grams.

3. 6·788 lit.

4. 1758·9 grams.

5. Nitrogen 42·42 per cent.
Hydrogen 9·09 per cent.
Oxygen 48·48 per cent.

6. 487·3 c.c. of each gas.

7. Nitrogen 35·9 per cent.
Hydrogen 7·7 per cent.
Carbon 15·4 per cent.
Oxygen 41 per cent.

8. 70·36 lit. nitric oxide.
109·277 lit. hydrogen.

9. NH_4HS.

10. Nitrogen 22·04 per cent.
Hydrogen 7·09 per cent.
Carbon 14·17 per cent.
Oxygen 56·69 per cent.

11. 26·791 grams.

12. $3{\cdot}\dot{6}\dot{3}$ pints.

13. Nitrogen 3·09 per cent.
Hydrogen ·88 per cent.
Aluminium 5·96 per cent.
Sulphur 14·14 per cent.
Oxygen 28·26 per cent.
Water 47·66 per cent.

14. 19·51 grams metaphosphate.
4·522 lit. ammonia.
44·99 lit. steam.

15. 23·97 grams !

16. 432·4 lit. !

17. 289·2 lit. !

18. 361·5 lit. !

19. 20·685 lit. !

20. 2·9755 lit. !

21. 557·25 grams water.
941·42 grams chloride.

22. 14·08.

CHAPTER XXV.

Calcium.

1. 560 c.c.

2. 1 814 371 grams.

3. 560 grams.

4. 1321·4 grams.

5. (α) 40. (β) 23·26.
(γ) 51·28. (δ) 17·09.

6. 2·017 kilos.

7. $7{\cdot}502 \times 10^{15}$ grams.

8. 602·7 cub. met.

9. $1{\cdot}155 \times 10^{8}$ litres.

10. $CaCO_3$.

11. 2·486 lit.

12. 470154 lit.

13. 13·6 grams.

14. 94·94 grams.

15. $Ca_3 2PO_4$.

16. $CaC_2O_4 . H_2O$.

17. 189·94 lit. chlorine.
685·04 grams dioxide.

18. 0·6 gram.

19. 26·45 c.c.

20. 97·3 grams.

21. $x \times 0{\cdot}01586$ grams ?

22. 2473·3 grams ?

23. 9·497 litres.

24. 42·45 kilos.

25. 1·88 gram carbon dioxide.

26. 0·0397 per cent. by vol.

CHAPTER XXVI.

STRONTIUM AND BARIUM.

	(α)	(β)	(γ)	(δ)	
1.	Sr 59·34	Sr 47·71	Ba 69·54	Ba 58·8	per cent.
	C 8·13	S 17·43	C 6·09	S 13·73	per cent.
	O 32·53	O 34·86	O 24·36	O 27·47	per cent.

2. 0·1805 c.m. 3. 0·0467. 4. 489·6 grams.
5. 586·2 grams. 6. 539·5 c.c.
7. 8·336 grams. 8. 1·728 grams ?
9. 69·53 per cent. 10. 31·523 lit.
11. 0·22088 cub. m. ? 12. 0·2962 gram.
13. 2·585 grams. 14. 0·04016 gram.
15. 15·147 lit. 16. 186·066 grams.
17. 24·77 grams chloride.
2·274 lit. dioxide. 18. 0·723 gram.
19. 3·253 grams. 20. 8·47 lit.
21. 9·48 lit. 22. 1·062 lit.
23. 6·27 grams barium.
0·336 gram calcium. 24. Sr=87·5?

CHAPTER XXVII.

ALUMINIUM.

1. (α) 12·85 grams.
(β) 5·695 grams. 2. 267 grams.
3. 6·72 lit. 4. $6\cdot\dot{2}$ lit.
5. 24·77 grams. 6. 32·84 lit. ?
7. 1·4 lit. 8. 11·26 grams.
9. 45·9 alumina.
54·1 silica. 10. 4 271 171·7 grams.
11. 4·944 lit. 12. 5·897 grams.
13. $[FeMg]O[Fe_2Al_2]O_3$. 14. Aluminium 14·06 per cent.
Sodium 11·98 per cent.
Chlorine 73·95 per cent.
15. Aluminium 45 per cent.
Oxygen 40 per cent.
Water 15 per cent. 16. $13\cdot\dot{8}$ grams.
17. 92·96 kilos.
18. 269·6.

19. 13·69 lit. !
20. 56·94 grams !
21. 7·16.
22. 7·0137 lit. !
23. $Al_6Na_8Si_7S_5O_{27}$.
24. 27·$\dot{3}$!
25. 15·56 lit. ? !
26. 0·2971 c.c. !
27. 4·472 lit. !
28. $([FeMg]O)_2(Al_2O_3)_9(SiO_2)_{43}(H_2O)_{22}$.

CHAPTER XXVIII.

MAGNESIUM.

1. (α) 285·71 grams.
   (β) 97·56 grams.
2. 5·112 yards.
3. 1·8$\dot{6}$ lit.
4. 9·$\dot{3}$ lit.
5. 30·69 grams.
6. 10·$\dot{6}$ lit.
7. 2·92 lit.
8. 42·17 kilos.
9. Magnesium 21·62 per cent.
   Phosphorus 27·93 per cent.
   Oxygen 50·45 per cent.
10. Magnesium 14·46 per cent.
    Silicon 25·3 per cent.
    Oxygen 38·55 per cent.
    Water 21·69 per cent.
11. Magnesium 13·04 per cent.
    Calcium 21·74 per cent.
    Carbon 13·04 per cent.
    Oxygen 52·18 per cent.
12. Magnesium 26·09 per cent.
    Silicon 20·29 per cent.
    Oxygen 40·58 per cent.
    Water 13·04 per cent.
13. 2·9285 kilos.
    266·$\dot{6}$ lit.
14. (α) 4·74 grams sodium carbonate.
    (β) 4·48 grams calcium carbonate.
    (γ) 3·76 grams magnesium carbonate.
15. 74·$\dot{6}$ lit.
16. 3·54.
17. 2·83.
18. 75 per cent. calcium carbonate.
    25 per cent. magnesium carbonate.
19. 24·006.
20. 12·13.
21. 20·1 c.c. !
22. 2·01 lit. !
23. 16·18 lit. !
24. 198·5 c.c. !

CHAPTER XXIX.

ZINC AND CADMIUM.

1. (α) Zinc 67·01 per cent.
   Sulphur 32·99 per cent.
2. 411·$\dot{6}$° C.
   1040° C.

(β) Zinc 52 per cent.
Carbon 9·6 per cent.
Oxygen 38·4 per cent.
3. $Zn_2SiO_4.H_2O$.
4. 1246·13 grams.
825·17 lit.
5. 6·892 lit.
6. Cadmium 77·$\dot{7}$ per cent.
Sulphur 22·$\dot{2}$ per cent.
7. 183 grams.
8. 397·95 lbs.
9. 120·2 lbs.
10. 1657·38 cub. met.
11. 82·2° C. 116·$\dot{6}$° C. 860° C.
12. 307·14 grams.
20 litres.
13. 112·6 · $CdCl_2$.
14. 289·1 grams !
15. 184·2 c.c. !
16. $Zn_8C_3O_{14} . 6H_2O$.
17. 22·24 grams !
18. $Cu_{37}Zn_{18}$.
19. $zn = 32{\cdot}4$!
20. 161·8 lit. !
261 seconds !
21. 10·79 grams !
22. $Zn(C_2H_5)_2$.

CHAPTER XXX.

MANGANESE.

1. (α) 63·2 per cent.
(β) 69·6 per cent.
2. 54·99.
3. 8·035.
4. 54·97.
5. 25·132 grams.
6. 77·46 grams manganese.
31·55 litres monoxide.
7. 44·8 lit. ?
8. 65·22 lit.
9. 40·5 grams.
10. 432·4 lbs.
11. Potassium 7·78 per cent.
Sulphur 12·74 per cent.
Manganese 10·95 per cent.
Oxygen 25·49 per cent.
Water 43·01 per cent.
12. 207·1 kilos.
13. Manganese 63·22 per cent.
Sulphur 36·78 per cent.
14. 1735·6 grams.
15. 43·208 lit.
16. 74·67 per cent. dioxide.
17. 4·76 lit.
18. 46·3 per cent.
19. 1·051 gram.
20. (i) 3·08609 grams.
(ii) 3·10$\dot{6}$ grams.
21. 10·645 kilos !
22. 42·33 cub. m.
23. 29·8 grams ? !
24. 10 per cent. water !

CHAPTER XXXI.

IRON.

1. 8539 grams.
2. 1507 grams.
3. 864 kilos.
4. 5·042 c.m.
5. 30·3688 grams.
6. 2680·95 grams.
7. 78·41 tons.
8. 141·78 kilos.
9. 786·41 m.m.
10. 5·215 tons.
11. 125·93 lit. ?
12. 58·8 grams.
13. 52·116 lit.
14. 393·36 lit.
15. Potassium 39·41 per cent.
   Iron 28·3 per cent.
   Oxygen 32·29 per cent.
16. 90 tons.
17. Iron 31·$\dot{1}$ per cent.
   Carbon 13·$\dot{3}$ per cent.
   Oxygen 35·$\dot{5}$ per cent.
   Water 20 per cent.
18. Iron 41·79 per cent.
   Carbon 8·96 per cent.
   Oxygen 35·82 per cent.
   Water 13·43 per cent.
19. 6578 cub. met.
20. 100·14 tons colcothar.
   111·41 tons acid.
21. 2·$\dot{6}$ lit.
22. Fe_23SO_4.
23. $(NH_4)_2 Fe_2 4SO_4 . 14H_2O$.
24. 218025·5 grams.
25. Iron 46·$\dot{6}$ per cent.
   Sulphur 53·$\dot{3}$ per cent.
26. 7·$\dot{7}$ lit.
27.

	(*a*)	(*β*)
Iron	94·92	97·38 per cent.
Carbon	5·08	2·62 per cent.

28. Iron 20·15 per cent.
   Sulphur 11·51 per cent.
   Oxygen 23·02 per cent.
   Water 45·32 per cent.
29. 2·946 grams.
30. 49·6 grams.
31. 2·25 c.m.
32. 325.
33. $2Fe_2O_3 . 3H_2O$.
34. Iron 56·75 per cent.
   Sulphur 43·25 per cent.
35. 16·$\dot{3}$ tons.
36.

	(*a*)	(*β*)
Iron	59·32	60 per cent.
Sulphur	40·68	40 per cent.

37. Fe_5N_2.
38. 42·$\dot{6}$ lit.
39. 5·8$\dot{6}$ lit.
40. 5·67 grams ?
41. 275·65 lit.
42. 132·22 lit.

43. 123·495 lit.
44. 27·12 grams.
45. 2·286 grams.
46. $FeI_2 5H_2O$.
47. fe=28·0002.
48. 1·771 grams.
49. 0·0531 grams.
50. 29·95 per cent. iron.
51. 0·8759 grams.
52. 1335 kilos.
53. 0·5646 gram.
54. 79·7 per cent. iron.
55. 0·04198 gram of iron in 1 c.c.
56. 4·9 grams.
57. 1503·7 lit.
58. 37·21 tonnes iron!
59. 70·95 lit. chloride!
17·74 lit. chlorine!?
60. Carbon comb. 0·627 per cent.
graph. 0·102 per cent.
Silicon 0·03 per cent.
Sulphur 0·005 per cent.
Manganese 0·12 per cent.
Iron and loss 99·116 per cent.
61. Iron 18·89 per cent.!
Ferrous oxide 81·11 per cent.!
62. $Fe_{11}O_{12}$.
63. 679 c.c. hydrogen!
64. Fe=56!?
65. $Fe_4S_3O_{12}$.
66. 90·28 lit.!

CHAPTER XXXII.

COBALT AND NICKEL.

1. CoAsS.
2. Nickel 78·38 per cent.
Oxygen 21·62 per cent.
3. Cobalt 20·99 per cent.
Sulphur 11·39 per cent.
Oxygen 22·77 per cent.
Water 44·84 per cent.
4. 42·706 lit.
5. 28·27 grams.
6. 74·48 grams.
7. 3·21 lit.
8. Nickel 11·82 per cent.
Potassium 31·89 per cent.
Nitrogen 17·13 per cent.
Oxygen 39·15 per cent.
9. 199·56 lit.
10. 1247·6 lit.
11. Potassium 35·29 per cent.
Cobalt 17·76 per cent.
Carbon 21·66 per cent.
Nitrogen 25·28 per cent.
12. 4·52 c.c.
13. 42·91 lit.
14. 1·517 lit.

15. $Fe_{12}Ni_5P_5$.
16. $(NH_3)_2NiSO_4$.
17. Cobalt 22·73 per cent.
    Chlorine 41·04 per cent.
    Nitrogen 26·97 per cent.
    Hydrogen 5·78 per cent.
    Water 3·47 per cent.
18. 59·03 !
19. 8·6 c.c.
20. $Co_3As_2O_8.\ 8H_2O$.
21. 85·72 per cent. cobalt.
22. 6·156 inches.

CHAPTER XXXIII.

CHROMIUM.

1. Iron 25 per cent.
   Chromium 46·42 per cent.
   Oxygen 28·58 per cent.
2. 63·99 grams.
3. Chromium 68·42 per cent.
   Oxygen 31·58 per cent.
4. 52.
5. 12·38 grams.
6. 51·977.
7. 13·839 lit.
8. (α) 6807·7 ft.
   (β) 8172·6 ft.
   (γ) 9652·3 ft.
9. 13·13 tons.
10. Chromium 62·65 per cent.
    Phosphorus 37·35 per cent.
11. 111·5 grams chromium.
    78·92 lit. monoxide.
12. $Cr_2O_3.\ 7H_2O$.
13. 340·3 c.c.
14. 5·75.
15. Potassium 22·4 per cent.
    Chlorine 20·33 per cent.
    Chromium 29·78 per cent.
    Oxygen 27·49 per cent.
16. 7·45 lit.
17. 52·4.
18. 131·58 grams sulphide.
    39·16 lit. dioxide.
19. 16·67 grams oxide.
    5·02 lit. chlorine.
    1·255 lit. oxygen.
20. $K_2Cr_3O_{10}$.
21. 11·035 lit.
22. $K_3CrC_6O_{12}$.
23. 31 grams.
24. 125 grams ! ?
25. 14·72 grams oxide.
    5·426 lit. oxygen !
26. 13·01 grams ! ?
27. 1·373 lit. !
28. 34·71 lit. !
29. 371·68 c.c. !
30. 10·11 lit. !
31. 95·9 grams !
32. 933·6 c.c. !
33. 16·32 lit. !
34. 6·653 lit. !

CHAPTER XXXIV.

TIN.

1. Tin 78·$\dot{6}$ per cent.
Oxygen 31·$\dot{3}$ per cent.
2. Cu_2FeSnS_4.
3. 51·67 grams.
4. 8·915.
5. 118.
6. 118·05.
7. 561·4 lit.
8. 6·809 lit. ?
9. (α) 259·28.
(β) 377·08.
10. 23·15 lit.
11. 415·82 lit.
12. 590·77 c.c.
13. 930·509 grams.
14. Hydrogen 0·84 per cent.
Tin 74·05 per cent.
Oxygen 25·1 per cent.
15. 11·994 lit.
16. SnS_2.
17. 1·963 lit. !
18. 31·37 lit. !
19. 8·65 lit. !
20. $Na_2SnO_3 . 4H_2O$.
21. 0·01335 c.m.
22. 0·030578 gram.
23. 3·544 lit. !
24. 0·0263 gram.
25. $H_8Sn_6O_{15}$.
26. 0·2692 gram !
27. $2NH_4Cl . SnCl_4$.
28. 114·668 grams.

CHAPTER XXXV.

LEAD.

1. 3062·4 lbs.
2. 43·63 kilos litharge.
2191·3 lit. oxygen.
3. (α) 68·31 per cent.
(β) 77·52 per cent.
4. 2007·34 lit.
5. 207·59.
6. 166 666 666.
7. 8·027.
8. 14·44 grams.
9. Lead 64·09 per cent.
Chromium 16·1 per cent.
Oxygen 19·81 per cent.
10. 207·1.
11. 11·37 kilos.
12. 54·6 per cent.
13. 791·55 grams.
14. 207·08.
15. 8·1 kilos.
16. 21·765 lit. !

17. 0·0012866 per cent. lead.
18. Carbonate 68·05 per cent.
Hydrate 30·71 per cent.
Impurities 1·24 per cent.
19. $PbClC_2H_3O_2$.
20. 24·85 lit. !
21. 673·7 grams.
179·4 lit. !
22. Pb_3O_4.
23. $Pb_3Cl_2O_7$.
24. 206·77.

CHAPTER XXXVI.

COPPER.

1. 63·17 ?
2. 142·7 c.c. sulphate.
84·77 grams copper.
3. 212·16 grams.
4. 3143·7 kilos.
5. 5682·3 grams.
6. 200·1.
7. 14·797 grams.
8. Copper 25·4 per cent.
Sulphur 12·83 per cent.
Oxygen 25·67 per cent.
Water 36·1 per cent.
9. 25·46 grams copper.
18·91 lit. steam.
10. $CuCO_3 . CuH_2O_2$.
11. 918·75 kilos. hyd. sulphate.
1168·6 kilos. copper sulphate ?
12. 26·69 lit.
13. 1·4027 grams.
14. 0·6567 gram.
15. 1·4491 lit.
16. 63·1.
17. 63·27.
18. 63 !
19. 19·278 lit. !
20. 20·37 lit. !
21. 9·446 lit. !
22. 25·32 per cent. copper.

CHAPTER XXXVII.

MERCURY.

1. 201·4.
2. 13·329.
3. 772·41 lit.
4. 199·72.
5. 944·8 c.c.
6. Mercury 82·42 per cent.
Sulphur 4·39 per cent.
Oxygen 13·19 per cent.
7. Mercury 71·7 per cent.
Hydrogen 0·36 per cent.
Nitrogen 5·02 per cent.
Oxygen 22·92 per cent.
8. Mercury 44·05 per cent.
Iodine 55·95 per cent.

9. 40·01 per cent. sodium. 10. 0·0344.
11. 2·341 lit. 12. Hg_2Cd.
13. 110·89 lit. 14. 94·36 c.c. mercury.
1·72 kilo. chloride.
15. 13·56. 16. 13·73 lit. !
17. 3·986 lit. ! 18. 38·49 grams !
19. 11·275 lit. ! 20. 2·658 grams !
21. 122° C. 22. Atomic weight = 200.
Molecular weight = 199·2.
23. 237. 24. Tin 21·21 per cent.
25. 20·1 m.m. ? Mercury 78·79 per cent.
Density 11·47.

CHAPTER XXXVIII.

SILVER.

1. 0·000682 c.m. diam. 2. Ag_3S_3As.
3. Δ10·37 if no change of vol. 4. 163·8 lbs.
100 vols. become 101·$\dot{6}$ vols.
5. 0·004015 m.m. radius. 6. 194234·94 shillings.
Weighing 16 950 878·7 grains.
7. 11·4815 grams ? 8. 107·99.
9. Silver 63·53 per cent. 10. 108·03.
Nitrogen 8·23 per cent. 11. 78·7 grams.
Oxygen 28·23 per cent. 12. 10·138.
13. 2·195 lit. 14. 272419 lit. ?
15. 107·05 ! 16. 534 c.c. !
17. 190·1 c.c. ! 18. 182·9 per cent. by vol.
0·02494 per cent. by mass.
19. 7·26 lit. ! 20. Silver 85·71 per cent.
21. 252·6 c.c. ! Hydrogen 0·4 per cent.
22. Ag_3Cu_2. Fluorine 7·54 per cent.
Oxygen 6·35 per cent.
23. $2AgCl. 3NH_3$. 99 grams chloride. 24. 542 c.c. !
$7AgCl. 10NH_3$. 100·45 grams chloride.
$16AgCl. 23NH_3$. 99·82 grams chloride.

CHAPTER XXXIX.

Gold.

1. 5181 sq. c.m.
2. 0·0023447 m.m.
3. 138759·83 sovereigns.
   17 105 479·28 grains.
4. 17·8.
5. 54·2134 kilos.
   2809 c.c.?
6. 336 c.c.
7. 49·349 c.c.
8. Gold 64·89 per cent.
   Chlorine 35·11 per cent.
9. 38·28 grams.
   3·9793 lit. chlorine.
10. 6·408 grams gold.
    2·322 lit. dioxide.
11. Nitrogen 3·73 per cent.
    Hydrogen 1·07 per cent.
    Gold 52·48 per cent.
    Chlorine 37·91 per cent.
    Water 4·81 per cent.
12. 2·703 grams.
13. 5·54 grams.
14. 12·24 c.m.
15. 2·575 kilos.
16. 0·00001098 c.m.
17. 13·6 mercury.
18. Au_7Cu_2; 91·54 per cent. gold.
19. 31·47 c.c.!
20. Au = 196·12.
21. AuO?
22. $Au_2O_34NH_3$ fulminating gold.

CHAPTER XL.

Platinum.

1. (α) Potassium 16·09 per cent.
   Platinum 40·1 per cent.
   Chlorine 43·81 per cent.
   (β) Nitrogen 6·3 per cent.
   Hydrogen 1·8 per cent.
   Platinum 43·9 per cent.
   Chlorine 48 per cent.
2. 24·8 lit.
3. Nitrogen 9·33 per cent.
   Hydrogen 2 per cent.
   Platinum 64·97 per cent.
   Chlorine 23·7 per cent.
4. 175·62 grams.
5. $N_4H_{12}PtCl_4$.
6. $Pt_{11}As_{21}$; 73·46 grams arsenic.
7. 197·721.
8. 14·71 lit.!
9. 52·15 grams!
10. 1520° C.?
11. 0·005782 gram.
12. (α) 0·42786 grains air.
    (β) 3·475 grains air.

TABLE I.

ATOMIC WEIGHTS.

The first column of numbers contains those given by Prof. F. W. Clarke as the most probable values obtained from all the best experiments. The second column contains the numbers used in this book.

Aluminium	Al.	27·009	27
Antimony	Sb.	119·955	120
Arsenic	As.	74·918	75
Barium	Ba.	136·763	137
Beryllium	Be.	9·085	
Bismuth	Bi.	207·523	208
Boron	B.	10·941	11
Bromine	Br.	79·768	80
Cadmium	Cd.	111·770	112
Cæsium	Cs.	132·583	
Calcium	Ca.	39·990	40
Carbon	C.	11·9736	12
Cerium	Ce.	140·424	
Chlorine	Cl.	35·370	35·5
Chromium	Cr.	52·009	52
Cobalt	Co.	58·887	59
Columbium (Niobium)	Nb.	94 ?	
Copper	Cu.	63·173	63·3
Didymium	D.	144·573	
Erbium	E.	165·891	
Fluorine	F.	18·984	19
Gallium	Ga.	68·854	
Gold	Au.	196·155	196·6
Hydrogen	H.	1·000	1
Indium	In.	113·398	
Iodine	I.	126·557	127
Iridium	Ir.	192·651	
Iron	Fe.	55·913	56
Lanthanum	La.	138·526	
Lead	Pb.	206·471	207
Lithium	Li.	7·0073	7
Magnesium	Mg.	23·959	24
Manganese	Mn.	53·906	55
Mercury	Hg.	199·712	200
Molybdenum	Mo.	95·527	
Nickel	Ni.	57·928	58
Nitrogen	N.	14·021	14
Osmium	Os.	198·494	
Oxygen	O.	15·9633	16

Palladium	Pd.	105·737	106
Phosphorus	P.	30·958	31
Platinum	Pt.	194·415	194·9
Potassium	K.	39·019	39·1
Rhodium	Rh.	104·055	
Rubidium	Rb.	85·251	
Ruthenium	Ru.	104·217	
Scandium	Sc.	43·980	
Selenium	Se.	78·797	79
Silver	Ag.	107·675	108
Silicon	Si.	28·195	28
Sodium	Na.	22·998	23
Strontium	Sr.	87·374	87·6
Sulphur	S.	31·984	32
Tantalum	Ta.	182·144	
Tellurium	Te.	127·960	128·3
Thallium	Tl.	203·715	
Thorium	Th.	233·414	
Tin	Sn.	117·698	118
Titanium	Ti.	49·846	
Tungsten (Wolfram)	W.	183·610	
Uranium	U.	238·482	
Vanadium	V.	51·256	
Yettrium	Y.	89·816	
Ytterbium	Yt.	172·761	
Zinc	Zn.	64·905	65
Zirconium	Zr.	89·367	

TABLE II.

THE ENGLISH AND METRIC MEASURES.

Measures of Length.

1 m.m. =0·0394 inches.
1 m. =39·3708 inches=3·2809 feet=1·0936 yards.
1 kilom.=0·6214 mile.
1 inch=25·4 m.m.
1 foot = 0·3048 m.
1 yard= 0·9144 m.
1 mile= 1·609 kilom.
1 knot= 1·855 kilom.

Measures of Area.

1 square metre=10·7643 sq. ft.=1·196 sq. yds.
1 square inch=6·4514 sq. c.m.
1 square foot = 929 sq. c.m.

Measures of Volume.

1 c.c. = 0·061 cub. inch.
1 lit. = 61·027 cub. inches = 0·03532 cub. ft. = 0·2201 gal.
1 cub. m. = 35·3166 cub. ft. = 220·0967 gal.
1 cub. inch = 16·386 c.c.
1 cub. foot = 28·3153 lit.
1 gallon = 4·5435 lit.

Measures of Mass.

1 gram = 15·432349 grains.
1 kilo. = 2·2046 lbs.
1 tonne = 0·9842 ton.
1 grain = 0·0648 gram.
1 ounce avoir. = 28·35 grams.
1 ounce Troy = 31·1035 grams.
1 pound avoir. = 453·593 grams.
1 hundredweight = 50·802 kilos.
1 ton = 1016·048 kilos.
1 kilogrammetre = 7·23308 foot-pounds.
1 foot-pound = 0·138254 kilogrammetre.

TABLE III.

CONVERSION OF PRESSURE IN ATMOSPHERES.

Atmospheres	Grams on sq. c.m.	M.m. of mercury	Inches of mercury	Lbs. on sq. inch	Feet of water
1	1033·3	760	29·922	14·7	33·9
2	2066·6	1520	59·844	29·4	67·8
3	3099·9	2280	89·765	44·1	101·7
4	4133·2	3040	119·687	58·8	135·6
5	5166·5	3800	149·609	73·5	169·5
6	6199·8	4560	179·531	88·2	203·4
7	7233·1	5320	209·453	102·9	237·3
8	8266·4	6080	239·374	117·6	271·2
9	9299·7	6840	269·296	132·3	305·1

TABLE IV.

TENSION OF AQUEOUS VAPOUR IN M.M. OF MERCURY.

t° C.	m.m.	t° C.	m.m.	t° C.	m.m.	t° C.	Atmos.
−10	2·08	16	13·54	90	525·39	100	1·0
−9	2·26	17	14·42	95	633·69	110	1·4
−8	2·46	18	15·36	99	733·21	120	1·96
−7	2·67	19	16·35	99·1	735·85	130	2·67
−6	2·89	20	17·39	99·2	738·50	140	3·57
−5	3·13	21	18·50	99·3	741·16	150	4·7
−4	3·39	22	19·66	99·4	743·83	160	6·1
−3	3·66	23	20·89	99·5	746·50	170	7·8
−2	3·96	24	22·18	99·6	749·18	180	9·9
−1	4·27	25	23·55	99·7	751·87	190	12·4
0	4·60	26	24·99	99·8	754·57	200	15·4
1	4·94	27	26·51	99·9	757·28	210	18·8
2	5·30	28	28·10	100	760·00	220	22·9
3	5·69	29	29·78	100·1	762·73	230	27·5
4	6·10	30	31·55	100·2	765·46		
5	6·53	35	41·83	100·3	768·20		
6	7·00	40	54·91	100·4	771·95		
7	7·49	45	71·39	100·5	773·71		
8	8·02	50	91·98	100·6	776·48		
9	8·57	55	117·48	100·7	779·26		
10	9·17	60	148·79	100·8	782·04		
11	9·79	65	186·94	100·9	784·83		
12	10·46	70	233·08	101	787·63		
13	11·16	75	288·50	105	906·41		
14	11·91	80	354·62	110	1075·37		
15	12·69	85	433·00				

TABLE V.

TENSION OF MERCURY-VAPOUR.

t° C.	m.m.	t° C.	m.m.
100	0·75	220	34·70
110	1·07	230	45·35
120	1·53	240	58·82
130	2·18	250	75·75
140	3·06	260	96·73
150	4·27	270	123·01
160	5·90	280	155·17
170	8·09	290	194·46
180	11·00	300	242·15
190	14·84	310	299·69
200	19·90	320	368·73
210	26·35	330	450·91

TABLE VI.

CONVERSION OF COLUMN OF WATER TO COLUMN OF MERCURY: AT THE TEMPERATURE OF 15° C.

Water	Mercury
1	0·0737
2	0·1474
3	0·2211
4	0·2948
5	0·3685
6	0·4421
7	0·5158
8	0·5895
9	0·6632

TABLE VII.

The Logarithms of 1 + ·00367 t.

t° C.	Log.	D.	t° C.	Log.	D.	t° C.	Log.	D.
– 30	$\bar{1}$·9493	18	120	·1585	11	255	·2869	8
– 20	$\bar{1}$·9669	17	125	·1640	11	260	·2910	8
– 10	$\bar{1}$·9838	16	130	·1694	11	265	·2950	8
0	·0000	16	135	·1748	11	270	·2991	8
5	·0079	16	140	·1801	11	275	·3030	8
10	·0157	15	145	·1853	10	280	·3070	8
15	·0233	15	150	·1905	10	285	·3109	8
20	·0308	15	155	·1956	10	290	·3148	8
25	·0381	15	160	·2006	10	295	·3186	8
30	·0454	14	165	·2056	10	300	·3224	8
35	·0525	14	170	·2106	10	305	·3262	7
40	·0595	14	175	·2154	10	310	·3299	7
45	·0664	14	180	·2203	10	315	·3337	7
50	·0732	13	185	·2250	9	320	·3373	7
55	·0799	13	190	·2298	9	325	·3410	7
60	·0864	13	195	·2344	9	330	·3446	7
65	·0929	13	200	·2391	9	335	·3482	7
70	·0993	13	205	·2436	9	340	·3518	7
75	·1056	12	210	·2481	9	345	·3553	7
80	·1118	12	215	·2526	9	350	·3588	7
85	·1179	12	220	·2571	9			
90	·1240	12	225	·2614	9	440	·4174	
95	·1299	12	230	·2658	9			
100	·1358	11	235	·2701	9	860	·6187	
105	·1416	11	240	·2743	9			
110	·1473	11	245	·2786	8	1040	·6828	
115	·1529	11	250	·2827	8			
					8			

TABLE VIII.

Volume and Density of Water (Rossetti) from the mean of all the best experiments.

t° C.	Volume at 4° C. = 1	True density grams in 1 c.c.	Volume in c.c. of 1 gram
0	1·000129	·999884	1·000116
1	1·000072	·999941	1·000059
2	1·000031	·999982	1·000018
3	1·000009	1·000004	·999996
4	1·000000	1·000013	·999987
5	1·000010	1·000003	·999997
6	1·000030	·999983	1·000017
7	1·000067	·999946	1·000054
8	1·000114	·999899	1·000101
9	1·000176	·999837	1·000163
10	1·000253	·999760	1·000240
11	1·000345	·999668	1·000332
12	1·000451	·999562	1·000438
13	1·000570	·999443	1·000557
14	1·000701	·999312	1·000688
15	1·000841	·999173	1·000828
16	1·000999	·999015	1·000986
17	1·001160	·998854	1·001147
18	1·001348	·998667	1·001335
19	1·001542	·998473	1·001529
20	1·001744	·998272	1·001731
21	1·001957	·998060	1·001944
22	1·002177	·997839	1·002164
23	1·002405	·997614	1·002392
24	1·002641	·997380	1·002628
25	1·002888	·997133	1·002875
26	1·003144	·996879	1·003131
27	1·003408	·996616	1·003395
28	1·003682	·996344	1·003669
29	1·003965	·996064	1·003952
30	1·004253	·995778	1·004240
40	1·007695	·99236	1·007682
50	1·011941	·98821	1·011928
60	1·016919	·98339	1·016906
70	1·022555	·97795	1·022542
80	1·028869	·97195	1·028856
90	1·035675	·96557	1·035662
100	1·043130	·95866	1·043117

TABLE IX.

VOLUME AND DENSITY OF MERCURY.

t° C.	Volume of mercury at 0° C. = 1	Density or grams in 1 c.c.	C.c. occupied by 1 gram	D.
0	1·000000	13·596	·073551	13
4	1·000716	13·586	·073605	12
5	1·000896	13·584	·073616	13
10	1·001792	13·572	·073681	14
15	1·002691	13·559	·073752	13
20	1·003590	13·547	·073817	13
30	1·005393	13·523	·073948	13
40	1·007201	13·498	·074085	13
50	1·009013	13·474	·074217	13
60	1·010831	13·450	·074349	13
70	1·012655	13·426	·074482	14
80	1·014482	13·401	·074621	13
90	1·016315	13·377	·074755	14
100	1·018153	13·353	·074890	

TABLE X.

THE DENSITIES OF SUBSTANCES; OR THE NUMBER OF GRAMS IN 1 C.C. OF THE SUBSTANCE.

N.B. The numbers can only be considered as approximate.

1. *Solid Elements:*		Iron, pure	7·88
Aluminium	2·67	„ wrought	7·7
Antimony	6·7	„ cast	7·1
Arsenic	5·7	„ steel	7·8
Barium	4·3	Lead	11·4
Bismuth	9·8	Lithium	0·59
Boron	2·7	Magnesium	1·74
Cadmium	8·7	Manganese	8
Calcium	1·58	Mercury at −40° C.	14·39
Carbon, diamond	3·514	Nickel	8·8
„ graphite	2·2	Phosphorus, yellow	1·837
„ charcoal	1·85	„ red	2·34
Chromium	5·9	Platinum	21·5
Cobalt	8·5	Potassium	0·87
Copper	8·9	Silicon	2·65
Gold	19·3	Silver	10·5
Iodine	4·95	Sodium	0·97

Strontium	2·54
Sulphur (octohedral)	2·05
Tin	7·3
Zinc	7
Brass	7·8—8·4
Bronze	8·4

2. *Solid Compounds:*

Ice	0·91674
Magnesia	3·19
Quicklime	3·2
Cupric oxide	6·4
Sodium chloride	2·06
Ammonium chloride	1·52
Potassium chlorate	2·32
Copper sulphate cryst.	2·27
Potassium nitrate	2·07
Ammonia alum	1·63
Silver nitrate	4·36
Potassium dichromate	2·6
Mercuric chloride	5·42
Lead chromate	6·1
Realgar	3·55
Mercuric sulphide	8·13
Potassium iodide	3
White lead	6·73
Rock crystal	2·65
Agate	2·58
Sand	1·42
Litharge	7·9
Minium	8·95
Hematite	5·075
Tinstone	6·95
Alumina (Emery)	3·9
Galena	7·4
Zinc blende	3·92
Stibnite	4·6
Marble	2·7
Iceland spar	2·75
Dolomite	2·92
Magnesite	3·04
Witherite	4·3
Strontianite	3·6
Gypsum	2·3
Celestine	3·9
Heavy spar	4·59
Fluor spar	3·2
Malachite	3·5
Steatite	2·8
Serpentine	2·6
Pumice-stone	2·3
Granite	2·7
Slate	2·85
Chalk	2?
Clay	1·92
Anthracite	1·6
Coal	1·33
Cane sugar	1·6
Amber	1·1
Ivory	1·92
Ebony	1·19
Oak	·69—·99
Box	0·96
Ash	0·753
Berlin porcelain	2·3
Green glass	2·64
Flint glass	3—3·5
Crown glass	2·5

3. *Liquids:*

Water (Table VIII.)	1·000013
Mercury (Table IX.)	13·596
Bromine	3·00
Water, sea-	1·026
Hydrogen sulphate	1·85
Hydrogen nitrate (70 per cent.)	1·42
Hydrogen chloride (40·8 per cent.)	1·2
Ammonia (33·5 p. c.)	0·89
Ethyl Alcohol, pure	0·791
„ proof spirit	0·916
Ether	0·715
Amyl alcohol	0·818
Benzene	0·85
Chloroform	1·5
Carbon disulphide	1·28
Turpentine	0·87
Glycerin	1·26
Olive oil	0·915
Milk (cow)	1·03
Blood (human)	1·055

4. *Gases:*

Hydrogen	·0000896
Air	·0012932

TABLE XI.

USEFUL CONSTANTS.

Circumference of a circle if $D=1$ (π)	3·1416
An arc equal in length to the radius in degrees (radian)	57·2958
Length of seconds-pendulum at London in metres	0·99413
Length of seconds-pendulum at London in inches	39·1393
Value of g. at London in metres per second	9·8117
Value of g. at Paris in metres per second	9·8094
Value of g. at London in feet per second	32·19
Mean radius of the Earth in metres	$6{\cdot}3703\times10^{6}$
Equatorial radius of the Earth in feet	$2{\cdot}092\times10^{7}$
Polar radius of the Earth in feet	$2{\cdot}085\times10^{7}$
Mean density of the Earth	5·67
Mass of the Earth in tons	6×10^{21}
Mean distance of the Moon (60·3 × radius of earth) in miles	238900
Mean distance of the Sun in miles	91 520 000
Normal height of the barometer in m.m. (Table III.)	760
Volume in litres of the molecular weight of a gas in grams	22·32
Double-density of air (mass of 22·32 litres)	28·872
Mass of a litre of normal hydrogen in grams (crith)	0·0896
Mass of a litre of normal air in grams	1·2932
Percentage of oxygen in air by mass	23·18
Percentage of oxygen in air by volume	20·9
Mass of a litre of water at 4° C. in grams	1000·013
Mass of a cubic foot of water at 4° C. in lbs.	62·425
Volume of a pound of water in cubic feet	0·01602
A 'horse power' in foot-pounds per second	550
A 'force de cheval' in kilogram-metres per second	75
Velocity of sound in air at 0° C. in metres per second	332·4
Velocity of light in air in metres per second	$3{\cdot}004\times10^{8}$
Velocity of the molecules of normal hydrogen in m. per sec.	1844
Wave length of the (mean) D line in m.m.	$5{\cdot}892\times10^{-4}$
Specific heat of copper	0·096
Specific heat of iron	0·114
Specific heat of mercury	0·033

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